SCIENCE ABSTRACTS.

Section A.—PHYSICS.

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SCIENCE ABSTRACTS.

Section A.—PHYSICS.

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GENERAL PHYSICS.

128. *Parallel Jet High-vacuum Pump.* **W. W. Crawford.** (Phys. Rev. 10. pp. 557–563, Nov., 1917.)—If a jet can be produced in which the molecules of vapour are moving in parallel directions with nearly equal velocities, then few collisions between the molecules of vapour would occur. Further, a gas molecule moving with the jet could enter it readily, but could not travel against the jet. The author has constructed pumps based on these principles, and entirely air-cooled. The nozzles used were of the divergent type common in steam-engineering practice, the throat being 0·24 cm. and the mouth 1·3 cm. in diam. The tube into which the vapour passed from the jet was from 2·5 to 5 cm. long and 2·5 cm. in diam., and beyond this was a larger chamber connected to the auxiliary pump. The jet disperses only slightly, and will, if of a proper density, entrain the gas to be pumped even if the pressure of the gas is not more than a thousandth of the computed internal pressure of the jet. Diagrams are given of two types which have been constructed. The speed of the pumps compares favourably with water-cooled mercury-vapour pumps [see Abs. 571 (1917)]. A. W.

129. *New Experiments on Shock Tests and on the Determination of Resilience.* **G. Charpy** and **A. Cornu-Thenard.** (Iron and Steel Inst., J. 96. pp. 61–104; Disc., 105–119, 1917. Engineering, 104. pp. 340–348; Disc., 323–324, Sept. 28, and pp. 371–375, Oct. 5, 1917. Met. and Chem. Eng. 17. pp. 397–407, Oct. 1, 1917.) —The authors have carried out researches with a view to clearly defining the method to be adopted in carrying out resilience tests. Great difficulties have previously been experienced in obtaining concordant results in impact testing. Some investigators attribute such irregularities to the method of testing, while others challenge the homogeneity of the metal under investigation. If the first view be correct it immediately stamps the test as practically useless, while the second view endows the bend test on notched bars with a degree of sensitivity not possessed by other mechanical tests. Preliminary experiments carried out on unnotched bars tested in such a way as to limit the deformation to a well-defined bend short of fracture showed that such bars, when tested with the same apparatus under similar conditions, give results

which are practically identical. Such regularity can only be obtained by careful preparation of the specimens and an accurate definition of the parts of the testing-machine in contact with the specimen. Further, the tests proved the irregularities displayed by different unnotched bars to be due to the material and not to the machine. In the preparation of samples of equal resilience from a 45-ton ingot of semi-hard steel it was observed that in order to get concordant results, extreme care had to be taken during heat treatment and that the outer layers of the lateral faces had to be removed after the heat treatment before carrying out the tests. The temperature of rolling was also found to influence the resilience in a very marked manner. Bars rolled at 800° and annealed at 900° C. gave a mean resilience of 29·05, while bars rolled at 1200° C. and similarly treated showed a resilience of 22·28. In the former case, however, the average divergence was of the order of 20·5 %, while in the latter case it was only 5·2 %. Further experiments were then carried out on copper, nickel steel, and nickel-chrome steel, the whole range having resiliences varying between 4·6 and 25·5. These results indicate that concordant results can be obtained from relatively small masses of metal, so long as the precautions outlined above have been taken. The authors then investigated the influence of the following variables: height of fall, weight of drop weight and anvil bars, type of machine, and type of notch. Within the limits generally employed in testing laboratories the rate of shock is negligible. Comparison of a 307-kg.-m. machine with a 30-kg.-m. machine in which the weights of the frame were 1800 kg. and 190 kg. respectively gave average results which differed from each other by only 0·74 kg.-m. It may therefore be concluded that the weights of the drop weights and anvil base are without any appreciable effect on the results of the test, since both machines were working under abnormal conditions; the large machine was unduly large, as the breakage of the test bars absorbed barely $\frac{1}{10}$ of the available energy, while in the unduly small machine practically the entire energy of the machine was absorbed in fracturing the test-piece. Further experiments showed that the results obtained with pendulum, vertical drop weight, and rotary (Guillery) machines were all perfectly comparable. The shape of the notch has an important bearing on the results. With brittle metals the resilience varies very little with the depth of a round notch; an angular notch gives slightly lower results than a round notch of the same depth. For non-brittle metals the resilience increases when the depth of the round notch diminishes. An angular notch gives lower results than a round notch of the same depth. In carrying out impact tests, therefore, it is imperative to employ only perfectly defined types of test-bars. Preference should be accorded to deep notches in order strictly to localise the fracture, but the radius of the cylindrical orifice appears to be of secondary importance. Resilience increases with the dimensions of the test-bars, but not in the same ratio for different materials. The increase is greater in brittle steel than ductile steel, and still greater in the case of copper. Experiments proved that the law of similitude does not apply to shock tests on notched bars. An appendix describes in detail the results of a series of tests carried out by the laboratory staff of the Conservatoire National des Arts et Métiers in the presence of the members of Committee 26 of the International Association for the Testing of Materials.

F. C. A. H. L.

130. *Attraction of a Hollow Cylinder.* **A. Riggenbach.** (Archives des Sciences, 44. pp. 346–348, Nov., 1917. Paper read before the Soc. Suisse de Géophys., Météorol. et Astron.)—The author, after pointing out the incon-

venience for numerical calculation of the formula usually employed in gravity determinations for the attraction of a homogeneous hollow cylinder upon a point situated on its axis, shows that by a simple substitution it may be transformed into a much more convenient shape. G. W. DE T

131. *Gravitation.* **V. Crémieu.** (Comptes Rendus, 165. pp. 586–589, Oct. 29, 1917.)—Previous researches [Abs. 31 (1907)] seemed to show that in a very convergent gravitation field bodies immersed in a liquid are subjected to something more than the difference between the hydrostatic pressure and the Newtonian attraction. This, however, was afterwards traced to variations in the effect of flexion at the points of attachment; but three years' work has failed to achieve precise measurements of the gravitation force within a liquid. Movement (rotation) of an attracting body produces no effect upon the attraction which it exercises, whether the movement be in a plane containing the line joining the attracted and the attracting body or at right angles to that line. The conditions of the experiment would have brought out an effect a hundred times as great as could be looked for in the case of the earth and the moon. [*Errata.* (Ibid. p. 688, Nov. 12, 1917.)] A. D.

132. *Gravitation.* **V. Crémieu.** (Comptes Rendus, 165. pp. 670–672, Nov. 12, 1917.)—Further experiments, designed to ascertain whether the mutual attraction of two bodies is affected by the neighbourhood of a third body rotating rapidly, have given negative results. A. D.

133. *The Flight of Projectiles.* **F. Burzio.** (Accad. Sci. Torino, Atti, 52. 11. pp. 445–458, and 52. 14. pp. 631–642, 1916–1917.)—These two papers discuss the problem of the motion of an oblong projectile relative to its centre of gravity and the deflections of the path of the centre of gravity from the plane of firing. Very much simplified equations are arrived at, which are applicable to the whole trajectory. A. D.

134. *On Einstein's Theory of Gravitation and its Astronomical Consequences.* Third paper. **W. de Sitter.** (Roy. Astron. Soc., M.N. 78. pp. 3–28, Nov., 1917.)—The paper is divided into seven sections. The first of these deals with the relativity of inertia. In Einstein's theory of general relativity there is no essential difference between gravitation and inertia, the combined effect of the two being described by the fundamental tensor $g_{\mu\nu}$, and how much of it is to be called inertia and how much gravitation is entirely arbitrary. Nevertheless it is convenient to make a difference, since part of the $g_{\mu\nu}$ can be directly traced to the effect of known material bodies, and the common usage is to call this part "gravitation," and the rest "inertia." All assumptions regarding the values of the $g_{\mu\nu}$ at infinity are extrapolations, which are free to be chosen in accordance with theoretical or philosophical requirements. The extrapolation which most naturally offers itself, and which is also tacitly made in Newton's theory of inertia, is that the $g_{\mu\nu}$ retain the values for all distances and times up to infinity. It has been pointed out in the second paper [Abs. 291 (1917)] that in this theory inertia is not relative, the boundary-values of the $g_{\mu\nu}$ at infinity being different for different systems of coordinates. Einstein and others have, therefore, tried to find another extrapolation by which the $g_{\mu\nu}$, while in our neighbourhood retaining values with the approximation demanded by the observations, would at infinity degenerate to a set of values that would be the same for all systems of reference. A new form of the field equations is developed, and two solutions A and B of these equations are given, namely, with and without world-matter. In Einstein's new

solution the three-dimensional world is not infinite but spherical or elliptical, and the existence of a "world-matter" is implied which fills the whole universe. Section 2 deals with the case of space with constant positive curvature, and with a comparison of the two systems A and B. Section 3 continues the comparison of the two systems from the standpoint of the course of the rays of light and parallax, and ends with a consideration of space with constant negative curvature, or hyperbolical space. Section 4 deals with the motion of a material particle in the inertial field of the two systems, and also gives a further comparison of the two systems. Section 5 investigates the differential equations for the gravitational field of the sun, and gives an approximate integration of these equations. Sections 6 and 7 deal with estimates of R (the radius of curvature) in the systems A and B. [Abs. 11 and 1077 (1917) should be consulted.] H. H. Ho.

135. *Astronomical Consequences of Electrical Theory of Matter.* **O. J. Lodge.** (Phil. Mag. 34. pp. 517–521, Dec., 1917.)—The author, although not seeing his way to controvert Eddington's conclusions [Abs. 1348 (1917)], urges that if the hypothesis be granted that inertia due to motion is not subject to gravity, the resulting perturbation for Mercury and Mars considered by him comes so near to explaining the outstanding discrepancies of the inner planets that the agreement can hardly be accidental. Moreover, if the inertia due to motion represents, as he believes, only ethereal reactions, then an astronomical perturbation is bound to occur in the case of rapidly moving planets, and it becomes merely a question of further calculation whether or not a solar drift can be chosen which shall give a result neither in excess for one planet nor in defect for another. Again, if v be the planet's orbital velocity, and V the sun's true proper motion—both vectors—the whole momentum is $m(v + V)$, and the force acting on it has the four terms $mdv/dt + vdm/dt + Vdm/dt + mdV/dt$. He took the first term only into account. Eddington showed the necessity of the second, and that it overpowers and just reverses the effect of the first. The third term, he finds, can give rise only to non-cumulative periodic effects. The fourth term he treats as zero. But this last would be illegitimate, if *e.g.* the sun were part of a rapidly moving spiral nebula: or if in any way *our* cosmic system were subject as a whole to acceleration, as some are beginning to suspect, it would give rise to curious, though minute, residual effects, especially on the outer planets, for resultant force would not then act, except on the average, along the radius vector of an orbit. G. W. de T.

136. *Physical Laws and Dimensions of Space.* **P. Ehrenfest.** (K. Akad. Amsterdam, Proc. 20. 2. pp. 200–209, 1917.)—The author propounds the problem of seeking for distinctive physical or geometric characteristics of three-dimensional space, and adduces three classes of phenomena which may apparently be taken as answers to some such question as, Why has our space just three dimensions? These are: (1) Gravitation and Planetary Motion. Let R_n signify a space of n dimensions, then it is shown that while in R_3 a sufficiently small disturbance leaves a circular trajectory finite, in R_2 this is the case whatever the energy of the disturbance. For $n>3$ any disturbance of a circular trajectory will cause the planet either ultimately to fall into the attracting centre or to go off to infinity, so that in such a space no motions comparable with the elliptic motions in R_3 can exist, all trajectories being of helical or spiral type. Moreover, Liebmann has shown [*Nicht-euclidische Geometrie*] that in a non-Euclidian three-dimensional space the planetary trajectories corresponding to our elliptic ones are found to remain closed when the necessary modifications,

corresponding to the curvature of the space, are made in the equations of motion and the expression of the law of gravitation. In this connection the author considers the question of Bohr's deduction of the spectra series, quantisising, with Bohr, the moment of momentum, and making the necessary modifications in the law of electric attraction, as in the case of gravitation. From what precedes, it follows that for $n>3$ circular trajectories only are possible. Assuming the radiation frequencies for all values of n, to be given by Bohr's equation $\nu_{\sigma,\tau}=(E_\sigma-E_\tau)/h$, it appears that for $n>4\nu_{\sigma,\tau}=\nu_0(\sigma^\kappa-\tau^\kappa)$, where κ is a positive fraction in general. Thus spectrum series are obtained which for constant τ and increasing σ contain lines in the ultra-violet at increasing distances apart. For $n=4$ a singular case occurs, the moment of momentum having a single perfectly defined value, $e\sqrt{m}$, so that the coefficient of attraction must be connected with h if the quantum condition is to hold good (necessarily with only one value of τ). The necessary modifications in the law of attraction in obtaining the equations of motion are deduced from the Laplace-Poisson equation expressing the condition that the force should be central and a function of r only, and so be derivable from a potential by the aid of Gauss' theorem for the integral of the normal component of the force over a closed surface. (2) Dualism between Translation and Rotation. This holds good only for $n=3$. For n co-ordinate axes determine $n(n-1)/2$ planes, and $n(n-1)/2=n$, only when $n=3$. Hence follows a similar dualism between electric and magnetic quantities only for $n=3$ in the ordinary electromagnetic theory. Moreover, from the formulæ of the relativity theory, it follows that if the electric field is determined by n numbers, the magnetic field will be determined by $n(n-2)/2$, leading to the same result. (3) Integrals of the Vibration Equation and Retarded Potentials. In R_3 the integrals of this equation, $1/c^2 . \partial^2\phi/\partial t^2-\Delta\phi=0$, are such that, if at the time $t=0$ ϕ and $\partial\phi/\partial t$ vanish everywhere except in a small domain γ, then at an arbitrary later moment t, if only t be taken large enough, they will still vanish everywhere except within a thin shell whose boundaries will in the limit, when γ becomes relatively small enough, become spherical surfaces having a common centre at γ. In R_2, *e.g.* in the vibration of a membrane, there is continued disturbance in a region included between two closed curves, one within the other and both enclosing γ, together with an asymptotically diminishing disturbance within the whole extension contained by the inner curve. And in this respect every R_{2n+1} behaves like R_3, and every R_{2n} behaves like R_2. But among the R_{2n+1}, R_3 is characterised by a unique singularity in the retarded potentials, *i.e.* the integral R_{2n+1}'s of the equation $1/c^2 . \partial^2\phi/\partial t^2-\Delta\phi=\rho$, in that they are functions of r and ρ only, the general solution for R_{2n+1} being a function of $r, \rho, \partial\rho/\partial t, \ldots \partial^{n-1}\rho/\partial t^{n-1}$. And for high values of r, which alone are concerned in the case of radiation problems, the highest differential coefficient is the most important, because here the lowest power of r occurs in the denominator. G. W. DE T.

137. *Oscillating Systems damped by Resistance as the Square of the Velocity.* **J. P. Van Zandt.** (Phys. Rev. 10. pp. 415–431, Nov., 1917.)—(1) A complete solution is here developed for the equation of motion $d^2\theta/dt^2+N(d\theta/dt)^2+M\theta=0$, subject only to one limitation, namely, that a certain function of the above quantities should differ from unity.

(2) The solution has been verified by comparison with the results of graphical integration and by experiment.

(3) The oscillations have been shown analytically and experimentally to be practically isochronous.

(4) A solution has been developed by which the numerical values of the successive turning-points may be computed.

(5) A model has been constructed suitable for a wide range of systems and by means of which it is possible to study oscillations damped by resistance proportional to the square of the velocity.

(6) A method is given for the determination of the coefficient of damping in terms of the values of the successive turning-points.

(7) The model developed may be extended to exhibit forced oscillations and various types of damping. E. H. B.

138. *Action of Coupled Circuits and Mechanical Analogies.* **H. C. Plummer.** (Phil. Mag. 34. pp. 510–517, Dec., 1917.)—Referring to a recent paper by E. H. Barton and H. M. Browning [see Abs. 1221 (1917)], Plummer expresses a doubt as to whether a simple electrical problem is made easier for the average student by a complicated mechanical analogy. He feels that, in the electrical problem, the difficulty begins and almost ends in establishing the fundamental equations. The mechanical analogy does not assist in this, but only in the subsequent interpretation.

It is then mentioned that equations (27) and (28) for one of the mechanical analogies may be rewritten in the form :—

$$(P + Q + \beta P)\frac{d^2y}{dt^2} + (P + Q)gl^{-1}y = -\beta Q\frac{d^2z}{dt^2}$$

$$(P + Q + \beta Q)\frac{d^2z}{dt} + (P + Q)gl^{-1}z = -\beta P\frac{d^2y}{dt^2}$$

which the author considers shows the analogy in a clearer light and makes it exact.

The equations of the electrical case are then written and discussed, the solution being presented in graphical form, giving the squares of the periods of the superposed coupled vibration in terms of those of the separate periods and the coefficients of coupling. An associated construction gives the relations of the periods themselves.

The equations of the electrical case are then dealt with in a less elementary way. They are cast into a form which suggests the mechanical analogy of a particle oscillating under gravity on a specified surface and near the origin of coordinates.

From another form of the equations of energy a second mechanical analogy is derived, namely, that of a sphere oscillating about a diameter under the action of springs on its trunnions, which are themselves pivoted in a ring capable of oscillation about a diameter inclined to the sphere's axis of oscillation. The angle between the two axes enters into the function which expresses the coupling.

The kinetic and potential energies are the same in the two problems and an exact analogy is established. The charges are represented by the angular displacements of the sphere and the ring. The acknowledged defects of this mechanism are the absence of symmetry and the fact that the coupling cannot be carried to unity unless the moment of inertia of the ring is zero.

E. H. B.

139. *Hydrodynamics of Relativity.* **C. E. Weatherburn.** (Cambridge Phil. Soc., Proc. 19. pp. 72–85, Oct., 1917.)—The author starts with Lamla's relativistic equations for the adiabatic motion of a frictionless fluid [see Abs. 29 (1912)]. These are transformed into a vector equation and, by the introduc-

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tion of functions analogous to those of Clebsch, a function $\mathbf{W} \equiv \frac{1}{2}\,\mathrm{curl}\,(k\mathbf{V})$ is obtained, k being a function defined by Lamla [*loc. cit.*], and employed in his equations of motion. The function $\mathbf{W}$ is shown to play the same part in the present analysis as that of $\frac{1}{2}\,\mathrm{curl}\,\mathbf{v}$ in the ordinary hydrodynamics. $\mathbf{W}$ may therefore be called the vorticity, and a line whose direction at any point is the direction of $\mathbf{W}$ at that point may be called a vortex line. The various familiar theorems in irrotational and vortex motion are then shown to hold in their new interpretations. But according to the relativity hypothesis no velocity can exceed that of light. An incompressible fluid is therefore an impossibility, for in it a wave would be propagated with infinite velocity. The theorems of ordinary hydrodynamics applying to incompressible fluids are shown to be represented by corresponding theorems referring to fluids of minimum compressibility, *i.e.* to fluids in which a wave could attain a velocity of propagation equal to that of light. G. W. DE T.

140. *Relativity Formulæ.* **C. Cailler.** (Archives des Sciences, 44. pp. 237–255, Oct., 1917.)—Mathematical treatment beginning with the transformation formulæ of Lorentz and then developing the subject by quaternions, biquaternions, four- and six-vectors. E. H. B.

141. *Size of Ultramicroscopic Particles.* **G. Laski.** (Akad. Wiss. Wien, Ber. 126. 2a. 1917. Ann. d. Physik, 53. 9. pp. 1–26, Oct. 2, 1917. Extract.)—A paper dealing with the determination of the size of ultramicroscopic particles by optical and mechanical effects. Experiments on the scattering of light by silver particles show that the radii of the particles dealt with ranged from 13×10^{-6} cm. to about 4×10^{-6} cm., the former giving an orange and the latter a purple colour. From the rate of fall of these particles the size could be calculated from the Stokes-Cunningham law, and a value of 7×10^{-6} cm. was thus found for the radius. A. W.

142. *On a Stable Crystal Lattice.* **R. Schachenmeier.** (Ann. d. Physik, 53. 9. pp. 79–96, Oct. 2, 1917.)—The gravitational theories of Abraham, Mie, and Einstein lead of necessity to the existence of gravitational waves. The two last-named authors opine it probable that these waves may never be experimentally observed. The present author, however, deems it not superfluous to investigate the nature of the effects produced should the waves occur with the necessary intensity. For this purpose he offers some considerations with respect to crystal lattices.

While the lattice structure of crystals may be experimentally demonstrated by Laue's diagram, yet the question of the stability of such a crystal lattice has never yet been completely explained. By the aid of gravitational waves a stable crystal lattice may be specified. Section I of the paper deals with the construction of a stable crystal lattice; Section II treats of the elastic properties of the crystal lattice; Section III discusses the relationship to known experimental physical constants; Section IV considers the thermal expansion of the crystal lattice. The qualitative and quantitative agreement with experience of the results hereby found appears to confirm the underlying theory. Also the evidence for the study of gravitation, which hitherto has been astronomical, is now supplemented by data from the inner processes of matter.

H. H. Ho.

143. *The Ether Hypothesis.* **G. Helm.** (Phys. Zeits. 18. pp. 456–461, Oct. 1, 1917.)—While the principle of relativity obviates the existence of the ether, the latter hypothesis has nevertheless rendered valuable service in the explanation of a multitude of natural phenomena. The author here deals with the question as to which theory can best account for the kinematics of continuity, and a previous paper [see Abs. 649 (1912)] on the principle of relativity in the ether hypothesis should also be consulted. The conclusions drawn are as follows:—The rigidly developed ether hypothesis offers a secure foundation for microphysical theories since it renders possible the adequate description of the phenomenon of action at a distance and also of the ordinary processes of mechanics. From the ether continuity with its complete system of continuous vector functions, there is evolved a generalised atomic conception as to the singular points of those functions regarded mathematically, which leads to the ideas of imaginary substances and processes of pseudo-continuity. From this mode of regarding the kinematics of continuity are deduced the radiation phenomena, together with electromagnetic processes in general.

H. H. Ho.

144. *Relativity.* **A. Palatini.** (N. Cimento, 14. pp. 12–54, July, 1917.) —Einstein's principle is elucidated and the mathematical working simplified. Application is made to the motion of a material point, to the motion of planets (Mercury), and to the bending of rays of light in a gravitational field.

A. D.

145. *Pressure of Air-bubbles in Glaciers.* **P. L. Mercanton.** (Archives des Sciences, 44. pp. 352–354, Nov., 1917. Paper read before the Soc. Suisse des Géophys., Météorol. et Astron.)—As the result of some experiments made at Borg in N.E. Greenland, Koch and Wegener found that the pressure of air-bubbles in glacier ice there was very high and of the order of 10 atmos. The corresponding value found by the author from experiments in Switzerland on the ice of the Saleinaz glacier is, on the contrary, low, of the order of one to two atmos. Further experiments are needed to determine whether the difference is due to experimental error or to a fundamental difference in properties of the two glaciers.

R. C.

146. *Periodic Disturbance of Level from Load of Neighbouring Oceanic Tides.* **K. Terazawa.** (Roy. Soc., Proc. 94. pp. 13–14, Nov. 5, 1917. Abstract.)—Hecker's Potsdam observations and those of Michelson at Chicago on the lunar perturbation of gravity, showed that the force apparently acting on a pendulum at either place is a larger fraction of the moon's direct attraction when it acts towards east or west than when it acts towards north or south. A calculation is made by the author to ascertain to what extent the tilting of the ground caused by the excess pressure of the tide in the North Atlantic is important for the explanation of this geodynamical discrepancy.

G. W. DE T.

147. *Errors in the Sum of a Number of Tabular Quantities.* **F. Schlesinger.** (Astron. J. 30. pp. 183–190, Sept. 26, 1917.)—A solution is given of the problem of determining the errors expected in taking the sum of any number of tabular quantities whose max. errors lie within specified limits. The problem was proposed by E. W. Brown as likely to be of importance in connection with the use of his new Lunar Tables.

C. P. B.

148. *Photographic Effective Wave-lengths of Spiral Nebulæ and Globular Clusters.* **K. Lundmark** and **B. Lindblad.** (Astrophys. J. 46. pp. 206–218, Oct., 1917. Astron. Nachr. No. 4907. Nature, 100. p. 212, Nov. 15, 1917.)—The method developed by Hertzsprung and Bergstrand [Abs 1195

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(1909)] for determining colour or spectral type by measurements of grating spectra has been extended by the authors of the present paper to the spiral nebulæ and globular clusters. Photographs have been obtained at the Upsala Observatory with the 6-in. Zeiss twin-astrographic telescope, fitted with triplet-lenses of 15 cm. aperture and 150 cm. focal length, and provided with a wire grating over the object-glass of one telescope. The calculated spectral types from the effective wave-length values agree very closely with the observed spectra from other sources. The results are considered to confirm the conclusions of Shapley, Hertzsprung, and others that no sensible absorption exists in space. C. P. B.

149. *Planetary Nebula, Jonckheere* 900. **R. Jonckheere.** (Observatory, No. 520. p. 459, Dec., 1917.)—As originally announced in 1912, this object was described as a new planetary nebula showing two small nuclei. Barnard has recently described it as a brightish, ill-defined, bluish-white disc, possibly a little brighter in the preceding part. The size of disc was in 1912 estimated as 8″, using a 14-in. telescope, whereas observing with the Yerkes 40-in. Barnard makes it 7·9″. The different measures of position seem to indicate a relative change of 1·5″ from 1912·72 to 1915·21. C. P. B.

150. *Corpuscular Theory of Aurora Borealis.* **C. Störmer.** (Terrest. Magn. 22. pp. 23–34, March, and pp. 97–112, Sept., 1917.)—Goldstein, in 1881, first published the idea that the terrestrial magnetic phenomena might be due to kathode rays emanating from the sun, and later Paulsen regarded the aurora as due to kathode rays originating in the upper strata of the terrestrial atmosphere. The first definite experiments supporting the corpuscular theory of the aurora were described by Birkeland in 1896, and the photographs shown of the deviations of kathode rays by a small spherical electromagnet exhibited many phenomena resembling the real atmospheric effects. The present paper contains a *résumé* of the author's theoretical calculations of the trajectories of electrical particles in the electric field of the earth, illustrated by photographs of wire models of the curves found. C. P. B.

151. *Preferential Motion of Planetary Nebulæ.* **C. D. Perrine.** (Astrophys. J. 46. pp. 175–178, Sept., 1917.)—From an analysis of radial velocities for 15 planetary nebulæ, it is shown that they show distinct preference for the regions of the vertices of ellipsoidal motion, particularly that near 18h. They are also considered as belonging to our stellar system. A diagram shows that the stellar planetary nebulæ are restricted to the Milky Way and Magellanic-clouds, and indicate a close relationship between the clouds and the Milky Way. C. P. B.

152. *Meteoritic Exchange of Solid Matter between Stellar Systems.* **E. Belot.** (Comptes Rendus, 165. pp. 501–503, Oct. 15, 1917.)—The author has previously given his views for believing that volcanic products emitted from the moon or other satellites may escape from the attraction of the satellites and travel through space [Abs. 750 (1917) and 19 (1918)]. Calculations are now made to determine what eruptive velocities are necessary to enable the meteorite to escape from the solar system entirely. Only the bodies of small mass, such as the satellites, are supposed capable of giving rise to these eruptions of space-penetrating materials. C. P. B.

LIGHT.

153. *Coloured Lines on Photographic Films.* **L. Dufay.** (La Nature, Nov. 10, 1917. Nature, 100. p. 290, Dec. 13, 1917. Abstract.)—The difficulty of getting coloured lines in exact juxtaposition and of sufficient fineness for the purposes of colour photography has apparently been completely overcome. The method is to pass a thin celluloid film between two rollers warmed sufficiently to render the celluloid plastic. One of the rollers has very fine circumferential parallel grooves of square section cut upon its surface, and thus the celluloid has similar grooves formed upon it. The film is then coated with a coloured transparent fatty mixture and wiped off, after the manner of wiping an etched plate after inking and before taking an impression from it. The film is next treated with an alcoholic solution of another colour, and this penetrates the exposed surface of the celluloid. Thus there are formed alternating coloured lines in perfect juxtaposition, which may be of a fineness as great as 30 lines to the millimetre. If the film is thin enough to permit of this without introducing the possibility of parallax, its other side may be similarly treated, either simultaneously or afterwards, so that two other colours may be introduced, or these may be added in the form of any microscopic figures that may be preferred. Three double pairs of colours are given: (1) Yellow and blue, red and green; (2) yellow and red, blue and orange; (3) red and blue, yellow and violet. A. E. G.

154. *Colours Diffusely Reflected from Collodion Films on Metal Surfaces.* **Rayleigh.** (Phil. Mag. 34. pp. 423–428, Nov., 1917.)—When a thin transparent film is backed by a perfect reflector, no colours should be visible, all the light being ultimately reflected, whatever the wave-length may be. An apparent exception has been described by R. W. Wood ["Physical Optics," 1914, p. 172]. A thin collodion film on a bright silver surface showed brilliant colours in reflected light, and scattered light of a colour complementary to the colour of the directly reflected light. No colours were shown when the commercial ether used as solvent was replaced by chemically pure ether obtained by distillation. In the former case, when sunlight was thrown upon the plate at normal incidence, brilliant colours were seen at grazing emergence when a Nicol prism was held before the eye; and the colours changed to the complementary tints on rotation of the nicol through 90°, *i.e.* in the scattered light, one half of the spectrum was polarised in one plane, and the remainder in a perpendicular plane. A similar observation had been described by Rowland in 1893 in a letter to the author. Similar films on glass do not show the effect, and the author points out that there are two possible explanations of the difference. One is, to suppose that the actual structure is different in the two cases; the other, apparently favoured by Wood, attributes the difference to the copious reflection of light from metallic surfaces. The author has not succeeded in carrying out any decisive test, but observes that on either view we may expect the result to be modified by the metallic reflection. Some explanation of the colours may be obtained by considering the action of an obstacle, such as a sphere, of a material slightly differing optically from its environment and situated in the neighbourhood of a perfectly reflecting plane surface upon which the light falls perpendicularly. The reflected light may then be supposed to consist of

plane waves undisturbed by the previous passage through and past the obstacle. The calculation, applying in the absence of a reflector but without limitation to the spherical form of the obstacle, was given in an early paper by the author [Phil. Mag. 12. p. 81, 1881; Sci. Papers, 1. p. 518]. Some of the analysis is outlined here, and the author points out that for the case of a very small obstacle, the colours due to a large number distributed at random may be inferred from the case of a single obstacle, but that if the distribution were in regular patterns complications would ensue from the necessity for taking phases into account. The random distribution suffices, however, in the present case, but the centres, or, more generally, corresponding points, of the obstacles may be taken as lying in a plane perpendicular to the direction of the primary light, and a solution is obtained on this basis, which accounts for colour formation. G. W. DE T.

155. *Sensibility of the Average Eye to Light of Different Colours.* **W. W. Coblentz** and **W. B. Emerson.** (Bureau of Standards, Bull. 14. pp. 167–286 [Sci. Papers, No. 303], 1917.)—The object of the investigation was the determination of the spectral visibility curve of the average eye, 130 subjects being tested, of whom 7 were known to be colour-blind. The distribution of energy in the source of light used, a cylindrical acetylene flame, was determined with great care, and visibility curves extending from 0·46 μ to 0·74 μ were obtained by using a flicker photometer. Observers experienced little difficulty in making settings with this instrument, but wide variations were met with when an equality-of-brightness photometer was used. It appears that age has a perceptible influence on the spectral visibility curve. Substantially the same results were obtained with the right and left eye respectively. The average position of max.-visibility, for 125 subjects, is located at 9·5576 μ. The average visibility curve is given. When corrected for selective transmission of ocular media, including the yellow spot, this produces a symmetrical curve with a maximum at 0·556 μ. The nature of the variations in different subjects is discussed in detail and they may be grouped in various ways. The observations confirm the impression that colour sense and brightness sense are independent. Calculations are presented showing that the eye can detect light of an intensity of 8×10^{-17} watt or 8×10^{-10} erg. J. S. D.

156. *The Fourth Colourless Sensation in the Three-sensation Spectrum, measured on the Centre of the Retina.* **W. de W. Abney.** (Roy. Soc., Proc. 94. pp. 1–13, Nov. 5, 1917.)—When the image of a small disc of spectrum colour impinges on the normal retina, its hue varies according to the region on which it falls, becoming paler and ultimately white as the periphery is approached. This white is referred to as the fourth sensation, incapable of resolution into red, green, and blue. It has been suggested that the cones on the retina are responsible for the colour-sensation, while the rods, which occur mainly in the peripheral regions, are responsible for the fourth "white" sensation. It is said that on the fovea only cones exist; but the author, in conjunction with W. Watson, finds that while on some retinæ light and colour both "go out" simultaneously as the illumination is diminished, in other cases the "white" impression persists after colour is lost, and is extinguished at a still lower illumination. This is presumptive evidence of the presence of rods on the retina, or possible intermediate organs. The present experiments were designed to test the behaviour of the fovea. Apparatus is described that enables spectrum visibility curves at very low illuminations to be determined, and a family of such curves, with

a common point of intersection, is shown. The results only partially support the theory based on the separate functions ascribed to rods and cones, and the latter appear to be sensitive to the same white rays as the rods, but in a minor degree. There is, however, an enormous difference in the sensitiveness of centre and periphery of retina respectively. The fourth sensation, in the former case, is imperceptible in comparison with the intensity of the spectrum colours in an ordinary spectrum, and therefore does not affect the sensation curves already published. It is hoped to extend the investigation to some congenitically night-blind subjects, presumed to have cones throughout the entire retina. An analytical note on the curves presented is added by **S. W. J. Smith,** in which it is pointed out that the curves form a concrete presentment of the argument in favour of the existence of the fourth sensation. J. S. D.

157. *Effect of Light on Pupillary Area and Retina of the Eye.* **P. Reeves.** (Eastman Kodak Co.'s Research Lab., Comm. No. 52. Ophthalmology, Otology, and Laryngology, J. Sept., 1917. Brit. J. Phot. p. 415, 1917. Frank. Inst., J. 184. pp. 717–719, Nov., 1917. Abstract.)—Tests on the capacity of the eye to perceive light are summarised [see also Abs. 49 (1918)]. When viewing a 1-mm. spot at a distance of 8 m. the minimum radiation visually perceptible was 17×10^{-10} erg. This quantity varies greatly according to the state of adaptation of the eye; thus under given conditions a dark-adapted eye could detect 44×10^{-7} millilambert, while an eye adapted to full sunlight could only distinguish 2 millilamberts. In ordinary vision the eye can detect a difference in brightness of 1¾ % between two adjacent fields. A dark-adapted eye can just tolerate exposure to a brightness of 25 millilamberts while, if adapted to bright sunlight, it could stand 16,000 millilamberts. The period of adaptation from brightness to darkness may occupy several hours and is least and takes place most slowly for red light, other colours following in the order, yellow, white, green, and blue. With a change in sensibility of the eye of over a million to one the pupillary diam. varies only from 16 to 1. The average diam. in dark adaptation was found to be 8 mm., and the average minimum diam. in bright light 2 mm. A table is presented showing values of the pupillary diam. with a brightness from 0·00015 to 2000 millilamberts. J. S. D.

158. *Irregular Assemblages of Pulses and their Actions on Resonators.* **T. Terada.** (Math. Phys. Soc., Tōkyō, Proc. 9. pp. 142-154, June, 1917.)—According to the modern views on the nature of radiation, white light as emitted by an incandescent body may be considered to consist of an irregular assemblage of electromagnetic pulses. As for X-rays, the *continuous* part of its spectra (obtained with the ordinary bulb) has usually been regarded as an assemblage of electromagnetic pulses produced by the collision of kathode rays upon metals, either according to the classical or the modern quantum theory. On the other hand, the systems of electrons constituting atoms or molecules are generally considered as resonators with proper natural modes of oscillations, with frequencies varying from the very high values corresponding to characteristic X-rays down to lower values corresponding to visible light or residual rays. Other phenomena such as the ionisation of gases, the photoelectric effect, fluorescence, photographic and other chemical effects, are moreover less related to the theoretical problem of the action of electromagnetic pulses on the atomic or molecular resonators, so long as the radiation may be considered as a succession of pulses.

The present paper initiates the mathematical theory which is to be applied to various special cases in later papers. E. H. B.

159. *High-frequency Spectra with Cylindrical Laminæ of Rock-salt.* **R[ita] Brunetti.** (N. Cimento, 13. pp. 224-240, April-May, 1917.)—The author uses curved laminæ of rock-salt for obtaining high-frequency spectra, the curved laminæ being obtained by pressing flat laminæ into shape when hot. This greatly facilitates the obtaining of certain experimental data. Data are given for iron, cobalt, and nickel. A. D.

160. *Resonance Radiation and the Quantum Theory.* **T. K. Chinmayam.** (Nature, 100. p. 284, Dec. 13, 1917.)—Silberstein recently gave an explanation of the resonance radiation of iodine vapour on the basis of classical dynamics by assuming that the resonators concerned were non-Hookean [Abs. 1348 (1916)]. On this theory the principal lines in the resonance series should appear at constant frequency-intervals, and to support this view Silberstein gave a tabular statement of the frequencies and their differences, based on the work of Wood. An examination of the figures shows, however, a decided tendency of the frequency-intervals to decrease on the long wave-length side. A table is here given in which it appears that the square roots of the frequencies, and not the frequencies themselves, show constant decrements, which fact rather suggests an analogy with Moseley's law for the high-frequency spectra of the elements. A. W.

161. *Ionisation and Single-lined Spectra.* **H. J. van der Bijl.** (Phys. Rev. 10. pp. 546-556, Nov., 1917.)—The results obtained by Franck and Hertz, McLennan and Henderson [Abs. 1583 and 1584 (1914)], Goucher [Abs. 64 (1917)], and others present two difficulties. First, although the result that the collision of an electron with an atom of a monatomic gas is elastic when the electron collides with energy less than a certain definite amount is in conformity with the quantum theory, such conformity does not exist if ionisation as well as radiation is produced by the transference of this definite amount of energy from the colliding electron to the atom. Secondly, the quantum theory requires that the transference of this amount of energy should give rise to the stimulation of a single line. But if, on the other hand, a stream of colliding electrons is used (as is always done) the emission of a single line is not compatible with Bohr's theory of the atom. In the present paper it is shown that a consideration of the three factors: (1) the increase in atomic potential energy by successive impacts, (2) the photoelectric effect of the light emitted by the stimulated atoms, and (3) the initial velocities of the electrons emitted from the kathode, affords an explanation of the results obtained by workers in this field. In particular, the recently published results of experiments of Goucher and of Millikan and Hebb [Abs. 779 and 1278 (1917)] are just what is to be expected from these considerations. The fact that Franck and Hertz, and McLennan, obtained single-line spectra is due, as Millikan also pointed out, to their probably not having used dense electron streams. The quantity which can be called the ionisation voltage of a gas or vapour is not necessarily the minimum voltage required to ionise the gas or vapour. This latter voltage depends more on extraneous conditions than on the nature of the substance, and cannot therefore be considered a property of the substance. According to the views here advanced, the ionisation voltage must be defined as the equivalent of the minimum energy necessary completely to detach an electron from the *normal atom.* This

quantity is a property of the substance only and is defined by the relation $V = h\nu_c/e$, where ν_c is the convergence frequency of the principal series, h is Planck's constant, and e the elementary charge. In view of the disturbing influences discussed in the present paper it would seem that the experimental determination of the ionisation voltage is not a simple matter. The observed ionisation at voltages below that required by the Bohr theory does not necessarily invalidate this theory. On the contrary, the fact that ionisation is observed to start at the voltages necessary to cause the minimum displacement of an electron from the outermost orbit of the normal atom, seems, on the basis of the interpretation given here, to lend support to the Bohr theory.
A. W.

162. *Wave-length of Light which Excites Fluorescence in Nitrogen.* **C. F. Meyer.** (Phys. Rev. 10. pp. 575–579, Nov., 1917.)—Wood and Hemsalech showed that the radiations exciting the nitrogen bands were transmitted in a slight degree through quartz, and Wood and Meyer subsequently showed that the radiations were possibly not far beyond the limit of the Schumann region, if indeed they were beyond it at all. In the experiments now described the light from the spark passed through a slot in a copper rivet, and was allowed to fall on a plane grating at an incidence of about 78°. The light reflected from the grating caused fluorescence in the path of the directly reflected beam and also in the first- and second-order spectra. Commercial nitrogen was used, and with the addition of a little moisture it was possible to limit the fluorescence to the water band λ3064. With a 30,000-line grating photographs were obtained which gave a result for the wave-length of the exciting light of 1300 Å.U., with a probable error of some 50 or 70 Å.U. The best plate shows the second-order diffracted beam quite unmistakably. As a result of the entire set of experiments it seems fairly certain that, at any rate, some of the radiations previously studied lie at the border of the Schumann region, and not beyond it. But it is difficult to account for the rather low transparency of good fluorite for the radiations, and the transparency of the air seems greater than would be expected. No actual measurements have been made of the transparency of the air. Wood suggests that the fluorescence may be excited simultaneously by the radiations here dealt with and by some of shorter wave-length which are not readily transmitted by fluorite or reflected by speculum metal. A rough estimate of the coefficient of reflection of speculum metal for the region near 1800 Å.U. may be made from the reflection experiments. It seems to lie between 5 % and 10 % at 75° incidence.
A. W.

163. *Total Emission of X-rays from Certain Metals.* **C. S. Brainin.** (Phys. Rev. 10. pp. 461–472, Nov., 1917.)—The paper describes a study of the total intensity of emission of X-rays from the six metals Pt, W, Ag, Mo, Cu, and Co over a range of voltages extending from about 5000 to about 33,000 volts. An investigation has been made of the relations between the energy radiated and the voltage, and between the energy and the atomic weight; this included a test of the validity of the equation $E = KAP^2$ due to Thomson [Phil. Mag., June, 1907]. Below 20,000 volts approximately the energy radiated by Pt and W was found not to be proportional to A and P^2; above this voltage, however, it is in agreement with the above relation. Molybdenum obeyed this relation throughout the range of voltages, and showed no deviation when the voltage was increased above the critical voltage for the K-radiation. Copper and cobalt seem to conform to this relation below their critical

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voltages for the K-radiations, but above those voltages their emission increased *more rapidly* than is required by the "voltage squared law." Silver also obeyed this law below the critical voltage for its characteristic K-radiation, but above that voltage the emission of energy increased *less rapidly* than is required by the "voltage squared law." A. B. W.

164. *A Determination of the Efficiency of Production of X-rays.* **P. T. Weeks.** (Phys. Rev. 10. pp. 564–574, Nov., 1917.)—The results of different observers on the efficiency of production of X-rays are not in good agreement. The present investigation was undertaken to make a new determination under more favourable conditions of better control of current and potential and larger power input made possible by the Coolidge tube. The energy given out in the form of X-rays was determined by means of the bolometer, and the energy supplied to the X-ray tube measured by its heating effect. The final results obtained are contained in the following table ;—

R.M.S. Kilovolts.	Input. $\frac{\text{Watts}}{\text{Amps.}}$	Obs. X-ray Energy. $\frac{\text{Joules}}{\text{Amp.-Secs.}}$	Efficiency without Correction.	Absorption Factor.	Total Energy. $\frac{\text{Joules}}{\text{Amp.-Secs.}}$	Total Efficiency.
28·3	35·1 × 10^3	17·1	0·49 × 10^{-3}	1·20	20·5	0·58 × 10^{-3}
31·6	39·2	23·4	0·60	1·17	27·4	0 70
34·5	42·8	30·7	0·72	1·15	35·3	0·82
37·1	46·0	38·3	0·83	1·13	43·2	0·94
39·5	48·9	46·3	0·95	1·11	51·3	1·05
41·6	51·5	52·3	1·02	1·10	57·5	1·15
43·5	53·9	59·3	1·10	1·09	64·6	1·20
45·2	56·1	66·9	1·20	1·08	72·3	1·29
48·2	59·8	84·3	1·41	1·07	90·2	1·51
50·8	63 0	93·6	1·49	1·07	100·2	1·59
53·9	66·8	118·0	1·77	1·06	125·1	1·87

The X-ray energy is nearly proportional to the cube of the potential across the tube. A comparison of these results with those obtained by others on the total ionisation produced by X-rays indicates that only a fraction of the energy of X-rays is transformed into the energy of the ions produced on total absorption in air. E. A. O.

165. *X-rays and the Theory of Radiation.* **C. G. Barkla.** (Roy. Soc., Phil. Trans. 217. pp. 315–360, Aug. 29, 1917—Bakerian Lecture).—[Further to Abs. 55 (1917).]—Experiments on (*a*) X-ray fluorescence (excitation by a primary X-radiation); (*b*) corpuscular radiation; (*c*) ionisation; (*d*) absorption, point to the existence of new series of characteristic radiations. All these methods show that under the usual conditions light elements emit characteristic radiations of moderate penetrating power, and that the higher the atomic weight of the element the more penetrating is its radiation. These radiations are much harder than those of the K-series of the light elements, so that they must constitute a new series of characteristic radiations, which is called the J-series since there is no evidence of an intermediate series. The mass absorption-coefficients for the radiations from nitrogen to sulphur have been measured in Al, and are found to vary from about 2·5 to 1·75. E. A. O.

166. *Absorption and Scattering of X-rays and the Characteristic Radiations of the J-series.* **C. G. Barkla and M[argaret] P. White.** (Phil. Mag. 34.

pp. 270–285, Oct., 1917.)—An account is given of some absorption experiments from which evidence is obtained that light elements emit, under suitable stimulus a hitherto unobserved characteristic X-radiation (a J-radiation). [See preceding Abs.] A full table is given of the absorption coefficients of X-rays having wave-lengths ranging from 0·145 × 10^{-8} cm. to 0·509 × 10^{-6} cm. in the five substances Cu, Al, water, paper and paraffin wax, the absorption in water and paper being equivalent to absorption in oxygen, and that in paraffin wax to absorption in carbon. The absorption in Cu is taken as the standard of reference because its K-spectral lines are fairly distant on the longer wave-length side, and its J-spectral lines (assuming they exist) must be somewhere on the shorter wave-length side of the J-radiations of the other substances. Plotting the absorptions in Al, O, and C as ordinates against absorption in Cu as abscissæ, the curves show certain discontinuities which must be associated with the J characteristic radiations of these substances; the curves show that the higher the atomic weight of the element the higher is the frequency of its characteristic wave-length, which fact is in harmony with the results obtained for K and L radiations. The wave-lengths obtained from the known relation between wave-length and absorption in Al are as follows: C, 0·42 × 10^{-8} cm.; O, 0·39 × 10^{-8} cm., Al, 0·37 × 10^{-8} cm.

In general the lower the atomic weight the greater is the proportion of loss by scattering to the total loss of energy. In O and C scattering accounts for almost the whole "absorption" within the range of the shortest wave-lengths dealt with. For X-radiation of very short wave-length, the value of the absorption coefficients in these substances becomes only slightly less than 0·2, which is the value of the scattering coefficient previously found by Barkla. This value 0·2 agrees almost perfectly with that obtained by calculation on the assumption that the number of electrons per atom is equal to the atomic number. It is pointed out, however, that the coefficient of absorption in Al sinks quite appreciably below 0·2 to a value 0·15 and that there is a tendency to still lower values. In the case of γ-rays values of μ/ρ as low as 0·04 have been obtained, which indicate that the simple law of scattering, *i.e.* approximate independence of wave-length, must break down for very short waves. The above results obtained in the case of Al with very short waves, point to the same conclusion, namely, that a diminution of scattering and absorption is setting in when the wave-length becomes small. This appears to be the link connecting the absorption of X-rays with the absorption of γ-rays. The absorption of γ-rays in substances of low atomic weight is almost entirely absorption by scattering.

It is shown that the relation between absorption coefficient and wave-length may be written in the form $\mu/\rho = C + kf(\lambda)$, where k depends only on the particular element. This relation represents the experimentally observed values fairly accurately over a limited range of wave-lengths when $f(\lambda) = \lambda^3$. It, however, does not express the fact of the variation of σ with λ, nor does $k\lambda^3$ appear to hold at all accurately except for wave-lengths far removed from those of the characteristic radiations excited in the absorbing substance.

E. A. O.

167. *X-ray Spectroscopy.* **E. Wagner.** (Phys. Zeits. 18. pp. 405–419, Sept. 1; 432–443, Sept. 15; 461–466, Oct. 1, and pp. 488–494, Oct. 15, 1917.)—A comprehensive account is given of the study of crystal structure and the characteristic radiation of the elements by means of X-rays. A fairly full description is given of the various methods of analysis, with a

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collection of results compiled from the work of the leading workers engaged in X-ray research. The importance of Moseley's investigations is emphasised and complete tables of the principal series of lines in the X-ray spectra of the elements are given. Comparative photographs of the "rotating" and "stationary" crystal methods are given in the case of the L-series of platinum.

After referring to the work of Rutherford and Andrade on the spectrum of γ-rays from RaB and C, the X-ray absorption and emission spectra of the elements are considered. It is clearly shown how Stokes' law is verified even for these extremely short wave-lengths.

In connection with the production of X-rays by kathode rays the importance of Einstein's relation $V_A e = h\nu_A$ is discussed and its consequences are demonstrated in particular cases.

A long discussion of the theory of X-ray spectra forms a conclusion. The spectral theory of Bohr and Moseley's law of frequencies and atomic numbers forms the basis of the discussion. A. B. W.

168. *X-ray Examination of the Crystal Structure of Chalcopyrite.* **C. L. Burdick** and **J. H. Ellis.** (Nat. Acad. Sci. Proc. 3. pp. 644–649, Nov., 1917. Am. Chem. Soc., J. 39. pp. 2518–2525, Dec., 1917.)—The method employed in this investigation is that of Bragg, slightly modified. The lattice is shown to be of the face-centred type. A difficulty which had to be surmounted was due to the fact that there is only a small difference of atomic weight between iron and copper, and their reflecting powers (as in the case of K and Cl in KCl) are not greatly different.

The model of the crystal, deduced from the observed X-ray reflections, gives a calculated density of 4·24, whilst the density of a crystal of chalcopyrite actually used was found by direct measurement to be 4·19.

A. B. W.

169. *Atomic Structure of Tungsten.* **P. Debye.** (Phys. Zeits. 18. pp. 483–488, Oct. 15, 1917.)—Gives the results of an X-ray investigation, by the method of Debye and Scherrer, of the crystal structure of tungsten. It is shown that tungsten crystallises in the cubic system, the side of the elementary cube having a length of $3{\cdot}18 \times 10^{-8}$ cm. This investigation brings out clearly the advantages of Debye and Scherrer's method of examination of crystal structure, especially in cases like the foregoing, where hardly any information as to the structure is available by other methods.

A. B. W.

RADIO-ACTIVITY.

170. *Radio-activity of Philippine Waters.* **J. R. Wright** and **G. W. Heise.** (J. Phys. Chem. 21. pp. 525–533, Oct., 1917.)—The radio-activity of about ninety different Philippine waters, chiefly from springs and flowing wells, has been studied. The highest RaEm content encountered in a deep-water well was equivalent to 2100×10^{-12} gm. of Ra per litre; the highest in spring water was equivalent to 1300×10^{-12} gm. of Ra per litre.

A test for the actual radium content of about 20 typical sources showed that the radio-activity encountered was due to emanation absorbed from materials with which the ground water had been in contact, and was not due to dissolved radium salts. One sample of water showed a scarcely detectable trace of activity due to radium salts in solution; all the others tested gave negative results. A. B. W.

171. *Distribution of Active Deposit of Radium in an Electric Field.* **S. Ratner.** (Phil. Mag. 34. pp. 429–448, Nov., 1917.)—A considerable amount of work dealing with the question of the distribution in an electric field of the active deposits from the emanations of radium, thorium, and actinium, has led to the general conclusion that the carriers of the active matter are positively charged. Great difficulties, however, have arisen from the fact that even with large electric forces a certain fraction of the active deposit appears on the anode.

The author now advances the hypothesis, supported by numerous experiments, that unchanged radio-active atoms are carried by the "electric wind" to the electrodes, independently of the sign of the electric field. The question immediately arises whether the origin of the anode activity may be traced to the same phenomenon. Experiments with "plate" and "needle" electrodes give conclusive proof that the concentration of active deposit on the electrodes is not entirely due to the electric force or to diffusion.

A method of concentrating the active deposit of radium on plates in the absence of an electric field is described.

The rate of recombination of radio-active ions is shown to be greater than that of ordinary gaseous ions. A. B. W.

172. *Diffusion of Actinium Emanation and the Range of Recoil from it.* **L. W. McKeehan.** (Phys. Rev. 10. pp. 473–482, Nov., 1917.)—The laws of ordinary gaseous diffusion and of radio-active recoil suffice to explain the principal effects observed in connection with the diffusion of and deposit from actinium emanation. The range of recoil from this emanation in air at normal pressure and at 20·7° C. is about 0·0092 cm.; the diffusion coefficient under the same conditions is about 0·109. Further investigation on some disturbing causes is proposed. A. B. W.

173. *Disintegration Constant of Radio-active Thorium.* **B. Walter.** (Phys. Zeits. 18. pp. 584–585, Dec. 15, 1917.)—Recently S. Meyer and F. Paneth have established that the hitherto accepted value of 2 years for the radio-activity of thorium to fall to half its value is too high, and that the max. interval does not exceed 1·9 years. A more exact value for this constant was not found to be attainable practically by the previous investigators owing to the specimen of radio-active thorium that was used being contaminated with mesothorium. Under these circumstances the present author has made a fresh determination of the constant with two radiothorium preparations which have been most thoroughly purified, and which he believes to be quite free from mesothorium or any other radio-active material. The apparatus used was similar to that of the above authors, with suitable modifications consequent on the much-reduced activity of the preparations used. These are given in detail. Two tables of results are shown from which the average value for the semi-activity period is found to be 1·876 years. The corresponding values of the disintegration constants λ are found to be $0{\cdot}3695\, a^{-1} = 1{\cdot}012 \times 10^{-3} d^{-1}$, and the average life of the substance $\tau = 2{\cdot}707a = 989$ days. H. H. Ho.

HEAT.

174. *Heats of Dilution: I. Calorimeter for measuring Heats of Dilution. II. Heat of Dilution of 8-N Ethyl Alcohol.* **D. A. MacInnes** and **J. M. Braham.** (Am. Chem. Soc., J. 39. pp. 2110–2126, Oct., 1917.)—The paper describes a calorimeter with accessories for the accurate measurement of heats of dilution, based on a modification of the adiabatic principle. A double-walled enclosure surrounds the calorimeter and is separated from it by a narrow air-gap. The temperature of the surrounding vessel is varied at the same rate as that of the calorimeter but is maintained at about 0·15 deg. below. By experiment it was found that for this difference of temperature the heat input due to stirring of the calorimeter contents was balanced by the heat loss from the walls by radiation, etc. The difference of temperature between the calorimeter and the surrounding vessel is observed by means of differential thermo-elements of which the sensitivity is such that a scale deflection of 40 mm. is obtained for 0·15 deg. difference of temperature.

In order to eliminate uncertainties concerning the thermal capacity of the calorimeter and its contents, a carefully measured amount of electrical energy is converted into heat in the calorimeter after each determination of the thermal effect of dilution and the corresponding rise of temperature measured. The heat of dilution is then obtained by calculation.

The dilution vessel is suspended and totally immersed within the calorimeter to ensure that the temperature of solvent and solution is identical before mixing.

Mixing is effected by pressing out stoppers from top and bottom of the dilution cup.

Various types of resistance thermometers have been tried for measuring the temperature changes of the calorimeter: the Heraeus type, consisting of a coil of very fine Pt-wire fused into quartz, proved unsatisfactory owing to the large heating effect of the measuring current and its sensitiveness to accidental jars. The calorimetric resistance thermometers of Dickinson and Mueller were adopted finally; with these, employing a specially designed bridge, temperature readings to 0·0001 deg. can be taken.

The data required in thermodynamical calculations is the "partial" or "reversible" heat of dilution, which may be defined as the heat evolved or absorbed on the addition of one mol of solvent to an infinite amount of solution. This quantity cannot be measured directly; a knowledge of the reversible heat of dilution can, however, be obtained by studying the effect of adding varying amounts of solvent to the solution. On dividing the values of the resulting heat effects by the corresponding number of mols of solvent added, a series of molal heats of dilution is obtained. If these molal heats of dilution are plotted as ordinates against the corresponding amounts of solvent as abscissæ a straight line is usually obtained which, when extended to the zero ordinate, gives the quantity sought.

By this procedure the "reversible" heat of dilution of 8-N ethyl alcohol solution was calculated to be 21·80. E. G.

175. *Ratio of Specific Heats of Hydrogen at 18° C. and at — 190° C.* **M[argaret] C. Shields.** (Phys. Rev. 10. pp. 525–540, Nov., 1917.)—(1) Observations by the Lummer and Pringsheim method in a 1-litre flask have been found to yield for air, $\gamma = 1{\cdot}4029$, a value in close agreement with already accepted values. (2) For hydrogen, γ is found to be 1·4012 at 18° C., 5 % lower than previous values, with no apparent explanation of the divergence. (3) For hydrogen at —191° C., γ becomes 1·592, in general accordance with the quantum theory of specific heats. [See Abs. 44 (1899) and 1690 (1914).] E. H. B.

176. *The "Uniform Movement" during the Propagation of Flame.* **W. Mason** and **R. V. Wheeler.** (Chem. Soc., J., Trans. 111. pp. 1044–1057, Nov., 1917.)—The initial slow propagation of flame that takes place when an inflammable mixture at rest is ignited at a point, is usually regarded as controlled by the transference by conduction of the heat developed by the combustion of the mixture immediately surrounding the point of ignition, whereby successive contiguous portions of the mixture are raised in temperature until chemical action becomes rapid. The initial speed of propagation of flame in a given mixture away from the point of ignition should mainly depend, according to this view, (1) on the conductivity for heat of the unburnt mixture, and (2) on the rate of change of reaction velocity with temperature. Under certain conditions, with all inflammable mixtures of gases and air at atmospheric temperature and pressure, the initial slow propagation of flame can be maintained at a uniform speed over a considerable distance of travel from the point of ignition. The conditions most favourable, or necessary, to obtain and maintain this "uniform movement" of flame are that the inflammable mixture should be contained in a long, straight, and horizontal tube open at one end and closed at the other; and that ignition should be effected at the open end of the tube by a source of heat not greatly exceeding in temperature the ignition-temperature of the mixture, and not productive of mechanical disturbance of the mixture. The speed of the uniform movement then depends on the composition of the mixture, and on the diam. of the tube in which it is contained. Above a certain small diam. the material of which the tube is made does not appreciably affect the speed of the flame. With a tube of given diam. the speed of the uniform movement of flame in a mixture can be regarded as a definite physical constant for that mixture. The authors examine Mallard and le Chatelier's theoretical considerations respecting the transference of heat during the burning of gaseous mixtures, in order to deduce the speed of the flame during uniform movement. They then proceed to discuss the question as to whether the layer of gas actually burning has a higher temperature than it would attain if it burned without previous heating to its ignition-temperature. Mallard and le Chatelier decided in the affirmative, but Haber and Richardt showed by actual thermo-electrical measurements that the surface of the inner cone of a Bunsen flame is not the hottest part of the flame, and they denied the possibility of the burning layer attaining a higher temperature during the uniform movement than it would if it were heated merely by its own heat of radiation.

The authors consider Haber and Richardt's view to be the correct one, and in order to obtain data whereby to test this conclusion and to elucidate the nature of the physical constant which they regard the uniform movement of flame to be, they have determined the speeds (in a tube 5 cm. in diam.) in a number of mixtures of methane, oxygen and nitrogen, of which they have also determined the relative ignition-temperatures, and of which the theoretical combustion-temperatures have been calculated. Experimental details are given. The results show the effect of reducing the oxygen content of the air on its ability to support the combustion of methane. The speeds of all the limit mixtures (in which a balance is struck between the heat generated on combustion and the heat required to start combustion) are the same. The uniform movement of flame as defined by Mallard and le Chatelier is found to be a strictly limited phenomenon obtainable only in tubes within a certain range of diam., large enough to prevent appreciable cooling by the walls, but narrow enough to suppress the influence of convection currents. The initial slow uniform movement can be regarded simply as a particular phase in the propagation of flame that results when ignition is effected (in a quiescent mixture) at the open end of a straight, horizontal tube of any diam. closed at the other end, and not as resulting from a particular mode of heat transference. H. H. Ho.

177. *Entropy of the Elements and the Third Law of Thermodynamics.* **G. N. Lewis** and **G. E. Gibson**. (Am. Chem. Soc., J. 39. pp. 2554–2581, Dec., 1917.)—The concept of entropy as developed by Clausius, which has always been regarded as an abstraction far less tangible than the concept of energy, was rendered more concrete by Boltzmann, who showed the intimate relation between the entropy of a system and the probability of the particular state in which the system exists. Planck has attempted to go farther and determine *à priori* the absolute probability of a system in any given state, but so far has not been fully successful. In recent years important discoveries relating to specific heat have brought to the fore the idea of entropy as a working principle, and a so-called third law of thermodynamics has been formulated which states that the entropy of every actual substance in the pure state is zero at the absolute zero of temperature. When Nernst first discussed the calculation of free energy from thermal data, he assumed the specific heat of solids and liquids to remain finite down to the absolute zero. It was not, however, this fact which caused confusion in what is called the Nernst heat theorem, but rather the inclusion of the "chemical constants" which were calculated for gaseous substances by a method first suggested by le Chatelier. The present authors now show that few, if any, of the tests of the third law of thermodynamics which have hitherto been made can be regarded as rigorous, but there are so many kinds of evidence which indicate the approximate validity of the law, and its inherent plausibility is such, that it has seemed desirable to assemble with some care the data which may be utilised in testing its validity, and in applying it to the calculations of free energies, if it prove tenable. The authors show that if the entropy of a substance is known at one temperature and the specific heat is known over a range of temperatures, then it is possible to calculate the entropy at another temperature by means of equations which are discussed at some length. If for the entropies thus obtained the heat of reaction is known, then the free energy change can be calculated. If the method employed is correct, then, in order to determine the free energy of formation of any compound from its elements, it will suffice to know the entropy of the substance, the entropy of the elements at the same temperature, and the heat of formation of the compound. The entropies of the elements in their standard states, at the standard temperature of free-energy measurements, namely 25°, are therefore data of the greatest significance, and the primary object of this paper is to obtain a comprehensive table of

these important quantities. Entropy and specific heat are discussed at some length. All substances which obey the equation $C_v = f(T/\theta)$, where T is the absolute temperature, θ a characteristic constant for each substance, and f the same function for different substances, and of which the heat capacity is the same function of T/θ as the heat capacity of the characteristic isotropic metals like copper or lead, are styled substances of Class I. The authors, instead of making any assumption as to the exact form of the heat-capacity equation, have employed a graphical method of calculating the entropy of solid substances which enables the fundamental principle involved in the above equation to be tested by inspection. A section with diagrams and tables is then devoted to the entropy of solid elements of Class I. The calculation of the entropy of substances which do not obey the above equation, *i.e.* elements of Class II, offers a problem of great difficulty, and for this purpose a formula $C_v = f(T^n/\theta^n)$ is proposed, where f is the same function as before and n is unity for substances of Class I and less than unity for all other substances. The only existing data for elements not of Class I, are in agreement with this equation within the limits of experimental error, and, although the data are rather meagre, the authors opine that the formula, while serving now as a first approximation may be found later to represent a general law. The entropies of the liquid and gaseous elements mercury, bromine, chlorine, oxygen, nitrogen, hydrogen, argon, helium, and also of carbon monoxide are next discussed. A section is then devoted to the entropies of a large number of compound substances. The final section deals with tests of the third law of thermodynamics and the calculation of entropies from this law. In nine cases direct tests of this law have been obtained, and the average discrepancy has proved to be 1·6 entropy units, or less than 500 cals. The authors believe these discrepancies lie within the limits of experimental error, especially as they are less in those cases where the experimental accuracy seems the greater. The hope is expressed that in the near future more accurate data concerning heats of reaction may be available, and in the meantime it is pointed out that the third law rests upon a more adequate experimental basis than either the first or second laws of thermodynamics possessed at the time of their universal adoption. The authors have therefore embodied the values of entropy obtained by means of the third law in their compilation of the atomic entropies of the elements, and they point out that the latter show with respect to atomic weight, or atomic number, the same sort of periodicity that occurs in other important atomic properties. H. H. Ho.

178. *Criteria for Grey Radiation.* **P. D. Foote.** (Washington Acad. Sci., J. 7. pp. 573–576, Nov. 19, 1917.)—In a recent paper [Abs. 1139 (1916)] Nutting has concluded that the logarithmic isochromatics for a black body cannot be stigmatic except approximately over a limited range of wavelengths, and that the condition of approximate intersection, and the condition for greyness of the radiator *may* both be satisfied, but either may hold without the other. The author points out that this is only the case where the term "logarithmic isochromatic" is used to designate the line (log radiant energy)—(reciprocal of absolute temperature). In the author's previous work [see Abs. 703 (1916)] the term is used to denote the line (ratio of radiation intensities of the radiator and a black body)—(reciprocal of absolute temperature). These latter lines are truly stigmatic for all grey radiators, but the stigmatic condition is not necessarily a criterion of greyness. J. W. T. W.

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SOUND.

179. *Number of Vibrations necessary for the Recognition of a Sound.* **A. Stefanini.** (N. Cimento, 13. pp. 65–107, Feb.–March, 1917.)—A very full *résumé* of previous work on this subject, and discussion of methods and sources of error. Low notes require a small number of vibrations, higher notes a greater number; *e.g.* frequency 64, vibrations 2 to 8; frequency 4096, vibrations 40. But there is an uncertainty arising from the difficulty of clearly specifying what the individual observer understands by the perception of tonality. The *consensus* of opinion is that two vibrations are enough: the first stimulates all the cochlear resonators, the second damps them all except the particular one appropriate, which is reinforced: but the nervous apparatus takes some time to react, during which time more vibrations have taken place. This time is longer, the feebler the sound: and it is not the same for all the regions of the cochlea. A. D.

180. *Screen against Sound and Vibrations.* **R. Ottenstein.** (Elekt. Zeits. 38. pp. 410–411, Aug. 9, 1917. Abstract of Dissertation, Munich, 1915.)—The object of this investigation was the most general treatment of the questions how to protect a region against air-sounds and *earth*-sounds, that is against vibrations propagated through the atmosphere and those propagated through the crust of the earth itself. Certain provisional results have been obtained with various materials, but need checking and extending before any standard practical method can be formulated. E. H. B.

181. *Acoustics of the Atmosphere.* **E. Schrödinger.** (Phys. Zeits. 18. pp. 445–453, Oct. 1, 1917.)—A mathematical treatment of sound propagation in an ideal atmosphere. Plane waves are first considered proceeding vertically, in an isothermal and still atmosphere with the usual barometric formula. It is thus shown that the amplitude varies inversely as the square root of the density. General wave motion is then dealt with, and it is here shown that the decrease of density above is exactly compensated by increase of amplitude, so that the radiation of energy proceeds as in a homogeneous medium. The influences of temperature gradient and chemical composition are next considered. Finally the attenuation of the sound due to viscosity is treated, the results being shown by graphs. [See Abs. 458 (1916).] E. H. B.

182. *Pitches of Pipes with Changes of Cross-section.* **P. Cermak.** (Ann. d. Physik, 53. 9. pp. 49–75, Oct. 2, 1917.)—The pitches of open and stopped pipes with one or more sudden changes of cross-section were experimentally determined. To fit these cases empirical formulæ were developed, which represent the phenomena with sufficient accuracy. Analogies from other kinds of vibrations are discussed. E. H. B.

183. *Abnormal Sound Radiation from Powerful Explosions and Gunfire.* **F. Nölke.** (Phys. Zeits. 18. pp. 501–504, Nov. 1, 1917.)—An enumeration of several heavy cannonades in the course of the present war, with the meteorological conditions prevailing at the times of cases involved. This is followed by a general descriptive discussion of the various views held to account for the silent zone and second audible region. E. H. B

ELECTRICITY AND MAGNETISM.

THEORY, ELECTROSTATICS, AND ATMOSPHERIC ELECTRICITY.

184. *Energy Flux in Electrodynamic Field.* **G. H. Livens.** (Phil. Mag. 34. pp. 385–404, Nov., 1917.)—Poynting's theory of energy flux in the electromagnetic field was objected to by Macdonald on the ground that Poynting's expression for the magnetic energy is not one that belongs to Maxwell's theory proper, and he proposed replacing it by one which gives for the energy flux vector Poynting's expression with a term added. The expression objected to has since been shown admissible in electrodynamic theory, and the author's object in the present investigation was to place Macdonald's theory on an exact theoretical basis under more general conditions than premised by him, mainly in order to examine it in sufficient detail to estimate its possibilities as an alternative to Poynting's theory. Let U be the total available electrodynamic energy inside a closed surface f, then assuming generally that decrease of energy within any closed surface is equal to flux outwards across the surface, we shall have $-dU/dt = \int_f S_n df$, S_n being the outward normal component of the flux vector S, and the integral being taken over the surface. Then $dU/dt = dV/dt + dT/dt + F$, where V is the potential energy, and T the kinetic energy, of the field within f, and F is the rate of working of the electrical forces converting purely electrical energy into energy of other types. Now, $V = 1/8\pi . \int_v E^2 dv$, and $F = \int_v (EC_1) dv$, where the volume integration is throughout the field within f, and C_1 is the part depending on the electrons of the total current C of Maxwell's theory. Then $C = C_1 + 1/4\pi . dE/dt$, so that $dU/dt = dT/dt + \int (EC) dv$. Hence—

$$\frac{dT}{dt} + \int_f S_n df = -\int_v (EC) dv, \text{.............................} (1)$$

a fundamental equation between S and T which must always be satisfied, being a consequence only of the energy principle and accepted electrodynamic theory. Transforming the volume integral by means of Ampère's circuital relation $C = c/4\pi . \text{curl } H$, and Faraday's relation $c \text{ Curl } E = -dB/dt$, we obtain the fundamental equation in a form convenient as a starting-point for the formulation of the several theories in question.

$$\frac{dT}{dt} + \int_f S_n df = \frac{c}{4\pi}\int_f [EH]_n df + \frac{1}{4\pi}\int_v \left(H\frac{dB}{dt}\right) dv \text{ ....} (2)$$

Poynting's theory is deducible directly from this; for if we take $T = 1/4\pi \int dv \int^B (H dB)$, we may also assume $S = c/4\pi . [EH]$, which is Poynting's vector. Macdonald's theory may be deduced from the same equation by using the relation $B = H + 4\pi I$, transforming the term $\int_v B^2 dv$ by the substitution $B = \text{curl } A$, where A is the vector potential, using Ampère's relation $C' = C + c \text{ Curl } I$, subject to the assumption that C' is the total current density, *including the effective representation of the magnetic distribution.* We may then take $T = 1/2c . \int_v (AC') dv - \int dv \int^B (I dB)$, and then assume also $S = c/4\pi . [EH] + 1/8\pi . d[AB]dt$, which is Macdonald's vector. But the procedure is unsatisfactory because: (1) It does not take account of the fact that a part of the total magnetic energy, corresponding to the magnetic polarisation of the media, is not effectively available mechanically; (2) the

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magnetic distribution in any arbitrary finite volume of space cannot be completely represented as a continuous current distribution throughout the volume, but must at least be supplemented by a distribution of surface currents over the boundary. The author discusses various alternative transformations, each giving a different expression for the energy flux vector S, and is of opinion that the procedure appearing to be the proper result in the simplest and most general form is obtained from the fundamental equation (1) by transforming the volume integral by means of the substitution $E = -dA/cdt - \text{grad. } \phi$, where A and ϕ are the vector and scalar potentials respectively, leading to an equation which can be satisfied by $T = 1/c \,.\, \int dv \int^{\wedge}(C dA)$, and $S = \phi C$. These various forms of a theory alternative to Poynting's theory of energy flux in the electromagnetic field have an advantage from the relativist point of view, in that the electrons occupy the more prominent positions, but they involve in their expression the scalar and vector potentials, the definitions of which are mathematically incomplete, and so cannot, without further arbitrary restrictions, represent definite physical entities. Even if this serious objection be waived, it is found that the new theory in its most generalised form, although it appears to be mathematically consistent, leads to conclusions quite incompatible with our usual preconceptions of the physical circumstances of radiation. Macdonald's form, while free from some of the fundamental difficulties of the generalised theory, appears inconsistent, both in its mathematical and physical foundations, and in the results to which it leads, so that both forms must apparently be rejected, and the author's conclusion is that Poynting's theory is the simplest and most definite theory consistent with the mathematical relation of the field and the physical processes occurring within it, and must stand as by far the most satisfactory yet suggested. G. W. DE T.

185. *Electronic Charge and Radiation Constants.* **L. Flamm.** (Phys. Zeits. 18. pp. 515–521, Nov. 1, 1917.)—A discussion of these constants as related on modern views. The discussion is mathematical and issues in the following connected values of electric and thermal constants.

$$
\begin{aligned}
N_{\infty} &= 109737{\cdot}11 \pm 0{\cdot}06 \\
\frac{e}{m} &= 1{\cdot}7686 \times 10^{7} \pm 0{\cdot}0029 \\
\text{(Millikan's value) } e &= 4{\cdot}774 \times 10^{-10} \pm 0{\cdot}005 \\
h &= 6{\cdot}545 \times 10^{-27} \pm 0{\cdot}012 \\
a &= 7{\cdot}295 \times 10^{-3} \pm 0{\cdot}005 \\
\Delta r &= 0{\cdot}3650 \pm 0{\cdot}0005 \\
c_2 &= 1{\cdot}4304 \pm 0{\cdot}0013 \\
\sigma &= 5{\cdot}738 \times 10^{-5} \pm 0{\cdot}011
\end{aligned}
$$

Also from Planck's theory the last constant has the form—

$$\sigma = 2\pi^5 k^4/(15c^2h^3)$$

[See Abs. 660 (1917).] E. H. B.

186. *Mechanical Theories of the Electromagnetic Field.* IV. and V. **A. Korn.** (Phys. Zeits. 18. pp. 539–542, Nov. 15, and pp. 581–584, Dec. 15, 1917.)—In Paper IV. the author considers the mechanical action upon a simple body together with the fundamental electrostatics of the problem. He first writes down the equations giving the form of the mechanical velocities in the electromagnetic field, based on previous fundamental assumptions [see Abs. 1071 (1917)]. From these he has recently developed the necessary differential equations and transformed them into a suitable

form for further investigation [see Abs. 88 (1918)]. The actual visible velocities are then determined. Following this comes a mathematical investigation of the electrostatics involved.

In Paper V. the mechanism of the electric current is investigated and, in particular, the varying mechanical action of a circular current is considered.

H. H. Ho.

187. *Some Fundamental Concepts of Electrical Theory.* **H. Bateman.** (Phil. Mag. 34. pp. 405–423, Nov., 1917.)—The author gives an introductory outline of an analysis, details of which he has dealt with in various mathematical journals, devised for developing electromagnetic theory on the basis of the concept of moving lines of electric force, and which may possibly lead to a determination of the validity or otherwise of J. J. Thomson's suggestion that tubes of electric force may be actual physical entities, not filling the whole of space, and therefore involving definite structure of the ether. The equations of the moving lines of force are assumed to be $X(x, y, z, t) = \text{const.}$, $Y(x, y, z, t) = \text{const.}$, where X and Y are uniform functions of the variables, and remain constant for any one line of force throughout its motion. Then if X, Y, be taken as coordinates of a point in a plane Π, there will be a one-to-one correspondence between the moving lines and the points in this plane. If C be a closed curve in the x,y,z space, specified at time t by $t = f(x, y, z)$ when f is a uniform continuous function, then to each point on it will correspond a point Q in Π, and as P describes C, Q will generally describe a curve Γ. Suppose C and Q both small closed curves, and the electromagnetic field such that the flux of force across C is $Zd\,(X, Y)$, where $d\,(X, Y)$ denotes the area of the curve Γ, and Z is a uniform function of x, y, z, t. If Z, X, Y be regarded as rectangular coordinates of a point M in a space ς, the flux is represented by the volume of a cylinder. Then the electric charge in a small closed volume in the x, y, z space will be represented by a volume element $d\,(X, Y, Z)$ in ς. Then assuming the elements of area and volume to be a small parallelogram and small parallelopiped respectively, and transforming accordingly, we find that, in the ordinary notation for Jacobians—

$$Zd(X,Y) = E_x d)y,z) + E_y d(z,x) + E_z d(x,y) - cH_x d(x,t) - cH_y d(y,t) - cH_z d(z,t),$$

$$d(X,Y,Z) = \rho d(x,y,z) - \rho v_x d(y,z,t) - \rho v_y d(z,x,t) - \rho v_z d(x,y,t),$$

where—

$$E_x = \partial(X,Y)/\partial(y,z), \quad H_x = -1/c\,.\,Z\partial(X,Y)/\partial(x,t), \quad \rho = \partial(X,Y,Z)/\partial(x,y,z),$$

$$\rho v_x = -\partial(X,Y,Z)/\partial(y,z,t).$$

Hence curl $\mathbf{H} = 1/c(\partial\mathbf{E}/\partial t + \rho\mathbf{V})$, $div\,\mathbf{E} = \rho$, so that if **E**,**H**, be taken as the electric and magnetic forces, ρ will represent the volume density of electricity, **V** the convection current, and c the velocity of light. Also $\mathbf{H} = 1/c\,.\,[\mathbf{VE}]$, the relation from which J. J. Thomson's theory starts, and from this relation it follows that $(\mathbf{EH}) = 0$, or **E** and **H** are perpendicular to each other. Similarly developing the theory of moving lines of magnetic force, and remembering that in the absence of free magnetism the flux of magnetic force across the boundary of a closed surface is zero, vectors **e** and **h** are obtained such that curl $\mathbf{e} = -1/c\,.\,\partial\mathbf{h}/\partial t$, div $\mathbf{h} = 0$; and therefore $(\mathbf{eh}) = 0$. The two theories are then unified simply by taking $\mathbf{E} = \mathbf{e}$ and $\mathbf{H} = \mathbf{h}$. A field in which $(\mathbf{EH}) = 0$ is called by the author a special field. Two special electromagnetic fields are defined as incident when there is permanent incidence between lines of electric force of the two fields, *i.e.* when they are such that if a line of force of one field intersects a particular line of force of the other field at any one instant, it will always intersect it. The condition for this, namely $\partial(X_1, Y_1 ; X_2, Y_2)/\partial(x, y, z, t) = 0$, is found to involve a similar relation between the functions determining the magnetic lines of force, and leads to simple vector expressions determining the mutual relations of the lines either of electric or magnetic force in the two fields. The author shows how the analysis may be extended to theoretically defined electromagnetic fields of more complex types, and several possibilities are suggested as worthy of discussion. G. W. DE T.

188. *Electric Charges on Spherules of Sulphur and Mercury determined from Fall Speeds and Colours.* **I[rene] Parankiewicz.** (Phys. Zeits. 18 pp. 567–574, Dec. 1, 1917.)—By Stokes's law with Cunningham's correction and by the resonance colours of the particles their sizes are determined and hence their charges. These charges on mercury droplets are determined as of the order 10^{-11} to 10^{-13} e.s. unit and show a distinct decrease with the capacity of the droplets. The smallest charge measured is stated to be $2{\cdot}68 \times 10^{-13}$ e.s. unit and was on a droplet of radius 2×10^{-6} cm.

Thus, taking the ordinary estimate $e = 4{\cdot}7 \times 10^{-10}$ e.s. unit, the charge here found is of the order of one 1800th of the elementary charge which is to be indivisible. E. H. B.

189. *Measurements of Atmospheric Electricity on Teneriffe.* **W. Buchheim** and **H. Dember.** (K. Sächs. Gesell. Wiss., Leipzig, 67. Dec., 1915. Ann. d. Physik. 53. 10. pp. 138–150, Oct. 26, 1917. Extract.)—Positive ionisation in the air over the peak of Teneriffe shows a maximum 2 to 3 hours after midday. This result is independent of the relative humidity, and it is therefore presumed that ultra-violet light or some other ionising agent is the cause of the ionisation.

The dry gases issuing from blowholes of the crater on the peak are found to possess an ionic density which is ten times that of the free air in the neighbourhood. [See Abs. 1075 (1912).] R. C.

190. *Diurnal Variation of Atmospheric Electrical Potential in Clear Weather.* **A. B. Chauveau.** (Comptes Rendus, 165. pp. 594–597, Oct. 29, 1917.)—The normal diurnal variation at a point near the ground shows a double oscillation with two minima, one in the afternoon, the other towards the end of the night, and two maxima, the first of which occurs some hours after sunrise and the second soon after sunset. At a sufficient height and also in winter at low altitudes the variation tends to become simple by the disappearance of the afternoon minimum. Thus it may be inferred that the true law of the variation is given by a simple oscillation, with maximum in the day and minimum in the night, and that at low stations this law is complicated by the disturbing effect of high temperature in the day or one of its concomitants, *e.g.* increased evaporation, solar radiation, and dryness. The following general explanation of these phenomena depends as regards the law on displacements of positive ions or particles charged positively, of atmospheric origin ; and as regards the disturbing effect, on displacements of negative ions emanating from the ground.

The earth is charged negatively, and hence there is by induction an excess of positive ions and particles in the lower layers of the atmosphere. Every cause of increase in the number of heavy particles, such as increased humidity, will result in an increase of the excess of positive ions near the ground, with consequent diminution of electrical potential. Thus is explained the minimum in the early morning. The maximum of the day according to the law is explained by the upward convective current carrying aloft the heavy positive ions and particles.

Similar reasoning will explain the disturbing effects already referred to if we replace positive ions by negative ions from the ground. These may be imparted to the air by (1) evaporation, (2) photoelectric action of solar radiation, (3) dust. From the fact that the effect is much less marked at the moderate elevation of the summit of the Eiffel Tower it is concluded that dust is probably the most effective agent for the transfer of the negative charges. R. C.

DISCHARGE AND OSCILLATIONS.

191. *Ionising Potentials of Gases.* **A. L. Hughes** and **A. A. Dixon.** (Phys. Rev. 10. pp. 495–514, Nov., 1917.)—Of the recent experiments on this subject the best known are those of Franck and Hertz [Abs. 659 (1913)]. During the past year the results of these experiments have been verified and extended by Goucher [Abs. 64 (1917)] and Bazzoni [Abs. 326 (1917)]. Yet up to the present the ionising potentials of only six or seven gases are known. It was thought that a systematic investigation of the ionising potentials of a number of gases—compounds as well as elements—would prove valuable.

The results are summarised in the following table, in which the values of the ionising potentials are given to the nearest tenth of a volt—an accuracy of not more than 0·2 or 0·3 volt being claimed. The experimental results of Franck and Hertz, Goucher, and Bazzoni are shown in the table, as well as the values predicted from Compton's theory.

Gas.	This Investigation.	Franck and Hertz.	Goucher.	Bazzoni.	Compton's Theory.
He	—	20·5	—	20·0	22·8
Ne	—	16	—	—	16·8
A	—	12	—	—	8·2
H_2	10·2	11	10·25 ?	—	11·8
O_2	9·2	9	—	—	8·4
N_2	7·7	7·5	7·4	—	8·05
S	8·3 ?	—	—	—	4·25
Cl_2	8·2	—	—	—	4·94
Br_2	10·0	—	—	—	—
Hg	10·2	—	10·0	—	4·65
HCl	9·5	—	—	—	6·50
CO	7·2	—	—	—	—
CO_2	10·0	—	—	—	6·47
NO	9·3	—	—	—	—
CH_4	9·5	—	—	—	6·54
C_2H_6	10·0	—	—	—	—
C_2H_4	9·9	—	—	—	—
C_2H_2	9·9	—	—	—	—

Several relations which might be expected to account for the values of the ionising potentials have been suggested, but the experimental values do not agree well with any of them. A. B. W.

192. *Electrodeless Ring Discharge.* **A. Hagenbach** and **W. Frey.** (Phys. Zeits. 18. pp. 544–547, Nov. 15, 1917.)—Describes a spectroscopic investigation of the electrodeless ring discharge [Abs. 136 (1914)] in the visible region of the spectrum. The substances dealt with were air, N, O, H, coal-gas, CO_2, carburetted hydrogen, I, S, Se, Te, P, Hg, Zn, and Cd. As the evacuation of the discharge tube was proceeded with, the contained gas

being air, the discharge at first took the form of a faintly luminous reddish ring, which at a certain pressure changed into very bright and almost white ring discharge. Further reduction of the pressure caused the ring to become more diffuse, and it gradually filled the whole discharge tube, until at the highest evacuation no discharge took place at all. In connection with the appearance of the spectrum of mercury, due to vapour from the evacuating pump, it was found that in the presence of phosphorus pentoxide the mercury spectrum almost completely disappeared, and though in only one case was it absent entirely, in general only the strongest lines appeared, so that the spectrum of the substance under investigation could be observed easily. Details are given of the spectrum obtained with the different substances dealt with. If the contained substance is air or nitrogen, an intense afterglow is obtained on breaking the discharge circuit, the pressure inside the tube being such as to give the bright and nearly white ring discharge. The intensity and duration of this afterglow depends on the pressure conditions, and its spectrum is the same whether air or nitrogen is used, consisting of six diffuse bands. The three strongest of these bands have approximately the wave-lengths 625, 565–575, and 495 $\mu\mu$. A. W.

193. *Anode Resistance Films.* **J. T. Tate** and **P. D. Foote.** (Washington Acad. Sci., J. 7. pp. 593–595, Dec. 4, 1917.)—In a previous paper [Abs. 1808 (1917)] it was concluded that a polarisation film of high resistance forms at the surface of a probe placed in the anode glow of a Wehnelt discharge tube. In the measurements referred to, the probe wire acted as an anode. Experiments have now been carried out with the probe acting as a kathode, and the results of these experiments are given in the present paper. The experimental arrangement was the same as in the earlier work. It is found that the resistance of the anode film is less than that of the kathode film, and the two types of polarisation resistance appear to be in a ratio of about the same order of magnitude as the ratio of the anode to the kathode fall of potential. The resistance of the anode film varies inversely with its area, but it should be emphasised that this relation was only tested for wires of the same diameter. On account of changes which would be produced in the character of the field it is probable that the relation would not hold for wires of different diameters. Skinner has found entirely different values of resistance per cm.^{2} for wires of different diameters. A. W.

194. *Duration of Luminosity of Electric Discharge in Gases and Vapours.* **R. J. Strutt.** (Roy. Soc., Proc. 94. pp. 88–99, Dec. 1, 1917.)—A continuation of previous work [Abs. 1533 (1914) and 167 (1915)]. The first experiments here dealt with were designed to observe the effects at very low gaseous pressures, and with small currents. The luminous particles in the jet are then comparatively free to move under the action of an external force, and their motion in an electrostatic field can be conveniently examined. Special care was taken to eliminate stray electric discharges. The gases investigated were hydrogen, oxygen, nitrogen, carbon dioxide, and mercury vapour. The shape of the luminous jet was very similar in all in the absence of an electric field. Photographs are reproduced of the varied effects obtained. The general result of the experiments is to show that the issuing stream of gas always contains luminous particles, negatively electrified, which may be deflected sideways by a transverse electric field. Sometimes also it contains luminous positive particles which may carry as much of the luminosity as the negative ones, or even more. The tendency of a lowering of pressure in the discharge vessel is to increase the number of positive particles. But the positive particles come into prominence much sooner in oxygen, nitrogen, or carbon dioxide than they do in hydrogen or mercury vapour. It is difficult to see how these experiments can be reconciled with the idea that the light is due to recombination of positive and negative ions. If this were so it would be expected that a separation of the two kinds of ions in a transverse field would lead to the extinction of all luminosity. Instead of this the two kinds of ions, separated by the field into distinct streams, show the same aggregate luminosity as before. Sometimes the luminosity is all in the stream which goes to the positive plate: sometimes both streams are about equally luminous. The streams lose their luminosity when they are discharged by contact with the plates. For these reasons the author regards the luminous centres as being excited before they have left the discharge tube. With a slight modification of an earlier apparatus experiments were also carried out at higher pressures, so that the discharge was more like a spark discharge than an ordinary vacuum discharge. The luminous effects were then much more pronounced, and could be examined spectroscopically. With hydrogen in the tube, and using a condensed discharge, the exuded jet of luminosity, about 9 mm. long, showed the Balmer series. The discharge spectrum shows widened lines, with the usual continuous background, but as the luminous gas emerges into the lower-pressure space the lines of the Balmer series become narrow, and the continuous background quite disappears, allowing the series to be photographed easily up to the tenth member. Nitrogen, in the same arrangement, with an uncondensed discharge, shows a jet with periodic swellings similar to those observed by Mach and by Salcher and Emden when a jet of compressed air, examined by the shadow method, escapes into the open. The wave-length agrees with that to be anticipated from their experiments. This nitrogen-jet luminosity is not to be confused in any way with active nitrogen. The time for which it endures is of quite a different order of magnitude, and the spectrum is essentially different. A. W.

195. *Diffraction of a Plane Electromagnetic Wave by a Perfectly Conducting Sphere.* **J. Proudman, A. T. Doodson, and G. Kennedy.** (Roy. Soc., Phil. Trans. 217. pp. 279–314, Aug. 15, 1917.)—The paper consists of tables and graphs of auxiliary functions involved in the investigation of this problem by T. J. I'A. Bromwich [not yet published]. Using polar co-ordinates r, θ, ϕ, the incident plane wave is taken to contain the time factor $e^{i\kappa ct}$, to travel along the negative direction of the axis $\theta = 0$, to be polarised in the plane $\phi = \pi/2$, and to have electric force of unit amplitude. The components of electric and magnetic force, in the disturbance produced by the sphere, along the direction of r, θ, ϕ, increasing, being X, Y, Z, and α, β, γ, it is found that at a distance from the sphere, large, compared with the wave-length of the incident train, $X = c\alpha = 0$, $Y = c\gamma = \partial M/\partial\theta - \partial N/\sin\phi\partial\theta$, $C = -c\beta = \partial M/\sin\theta\partial\phi + \partial N/\partial\theta$, where—

$$M = \cos\phi \frac{e^{-i\kappa(r-ct)}}{\kappa r} \sin\theta \sum_{n=1}^{\infty} (-1)^{n+1} \frac{2n+1}{n(n+1)} \cdot \frac{S'_n(\kappa a)}{E'_n(\kappa a)} P'_n \cos\theta,$$

and N an expression derived from this by replacing the factor $S'_n(\kappa a)/E'_n(\kappa a)$ by $S_n(\kappa a)/E_n(\kappa a)$. Then writing—

$$Y = \cos\phi \frac{e^{-i\kappa(r-ct)}}{\kappa r} (Y_1 + iY_2),\ Z = \sin\phi \frac{e^{-i\kappa(r-ct)}}{\kappa r} (Z_1 + iZ_2),$$

where Y_1, Y_2, Z_1, Z_2 are real, the time-means of the squares of the real parts of Y and Z are respectively $\frac{1}{2}\frac{\cos^2\phi}{(\kappa r)^2}(Y_1^2+Y_2^2)$ and $\frac{1}{2}\frac{\sin^2\phi}{(\kappa r)^2}(Z_1^2+Z_2^2)$. And these measure the energy of the disturbance. The Y_1, Y_2, Z_1, Z_2 involve only κa and θ, and they, together with $Y_1^2+Y_2^2$ and $Z_1^2+Z_2^2$ are calculated and tabulated, and their graphs drawn, for certain values of κa and for all values of θ from 0 to π. The work has been extremely laborious and has involved the construction of tables for Bessel's functions of half-integral orders [see B.A. Report, p. 87, 1914], and tables of the derivatives of Legendre's functions, which will shortly be presented to the British Association.

G. W. DE T.

196. *Dynamical Characteristics of X-ray Tubes.* **N[ella] Mortara.** (N. Cimento, 13. pp. 265–270, April–May, 1917.)—The tubes used in previous investigations [Abs. 1085 (1917)] all had small antikathodes. If the antikathodes be massive and the tubes hard, the V*i* curves are curvilinear. Coolidge tubes are peculiar: the intensity is practically constant, while the instantaneous potential varies according to different laws, which depend on the exciting apparatus.

A. D.

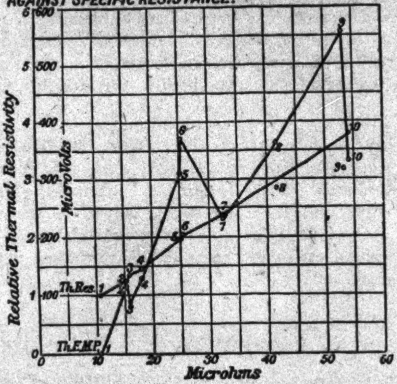
ELECTRICAL PROPERTIES AND INSTRUMENTS.

197. *Influence of Heat Treatment on the Electrical Properties of Steel.* **E. D. Campbell** and **W. C. Dowd.** (Iron and Steel Inst., J. 96 pp., 1917. Engineering, 104. pp. 422–423, Oct. 19, 1917. Met. and Chem. Eng., 18. pp. 86–90, Jan. 15, 1918.)—In previous papers E. D. Campbell [see Abs. 1781 (1915), 403 (1916)] has given experimental evidence to support the conception that the total electrical resistivity of steel may be considered as made up of two components: (1) due to the solvent, and (2) due to the carbides in solution. Frequently 80 % or more of the electrical resistivity is due to the solutes. Also if carbides are the only solutes present in noticeable amounts the thermoelectric force due to dissolved carbides is a function of the concentration. The present investigation is a preliminary study of the correlation of electrical and thermal properties of steels from the point of view of this solution theory. Ten different samples of steel were investigated in the annealed and hardened states. The table shows their percentage compositions.

Steel.	C	Mn	P	S	Si	Cu	Ni	Cr
1	0·018	0·016	0·005	0·018	—	0·018	—	—
2	0·57	0·11	0·010	0·020	0·17	—	—	—
3	1·184	0·016	0·005	0·018	—	0·018	—	—
4	0·945	0·189	0·013	0·016	0·155	—	—	—
5	0·18	0·67	0·007	0·019	0·16	—	3·45	—
6	0·326	0·405	0·013	0·026	0·162	—	4·48	—
7	0·14	0·44	0·009	0·008	0·11	—	4·12	1·61
8	1·110	0·40	0·020	0·038	1·20	0·06	0·31	0·348
9	0·104	0·122	0·03	0·025	3·649	—	—	—
10	1·150	11·57	0·055	0·023	0·25	—	—	—

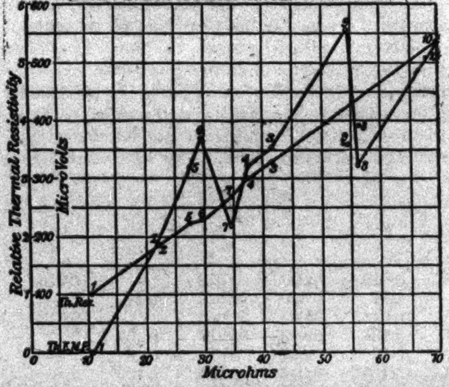
The specific electrical resistances were measured at 25° C. The thermal conductivity of the various samples was measured relative to pure ingot iron (=1), the mean temperature of the specimen not exceeding 40° C. Thermoelectric forces were determined by forming a couple with pure ingot iron, the junctions being at 0° and 25° C. The results are represented

Fig.1. CURVES SHOWING RELATIVE THERMAL RESISTIVITY & THERMO E.M.F. OF ANNEALED STEELS PLOTTED AGAINST SPECIFIC RESISTANCE.



graphically in the Figs., the reciprocal of the relative thermal conductivity being plotted.

Fig.2. CURVES SHOWING RELATIVE THERMAL RESISTIVITY & THERMO E.M.F. OF HARDENED STEELS PLOTTED AGAINST SPECIFIC RESISTANCE.



The ratio of the electrical resistivity to the relative thermal resistivity of pure iron is 10·64. The authors obtain an analogous ratio for the effect of the solutes by subtracting 10·64 from the total electric resistivity and 1 from the relative thermal resistivity. This ratio varies from 14·8 to 19·7 in the case of the annealed specimens and from 13·4 to 14·7 for the hardened specimens. The highest ratio is that due to sample 9, in which the solute is

V.2
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almost wholly silicide. Quenching increases both the electrical and thermal resistivity, the extent of this change being closely connected with the percentage of C. The carbons precipitated from the solution when the steel is annealed again pass into solid solution when heated above Ac3 just before quenching. The curves show the thermoelectric force to be dependent upon the chemical composition of the solutes as well as upon their concentration. The authors suppose the thermoelectric forces of the solutes in solid solution to be analogous to the solution tension of electrolytes in aqueous solutions. Heat treatment will change the concentration of the solutes in solution. Thus, when the thermo-e.m.f. of the solute, other than carbides, is higher than that due to carbides, the thermo-e.m.f. of such steels in the hardened condition tends to be lower than that in the annealed state. This is illustrated in the case of (8), although quenching increases the electrical and thermal resistances, owing to increased concentration of solutes in solution.

L. L.

ALTERNATING CURRENTS AND MAGNETISM.

198. *Magnetic State of Greenland Basalt.* **P. L. Mercanton.** (Archives des Sciences, 44. pp. 359–361, Nov., 1917. Paper read before the Soc. Suisse de Géophys., Météorol. et Astron. Comptes Rendus, 165. pp. 632–634, Nov. 5, 1917.)—Having obtained specimens of tertiary basalt during the stay of the Swiss Greenland Expedition of 1912–13 on the island of Disco, the author had these ground to cubical shape, care being taken to retain their geographical orientation. On testing these blocks, of 2 to 5 cm. edge, it was found that in two cases the lower horizontal surfaces had north magnetic polarity, whereas in the other six cases the polarity of the lower face was of the opposite kind. The magnetisation of basalt is thus sometimes in the direction opposite to that which the earth's field would produce at the present time. Further research is necessary in order to determine whether the result has been caused by an actual reversal of the earth's field or to some other cause. [See also Abs. 1506 (1900) and 628, 629, 1157 (1904).]

G. E. A.

199. *Analytical Representation of Magnetic Hysteresis.* **F. Piola.** (Elettrotecnica, 4. pp. 554–560, Nov. 5, 1917.)—In the analytical developments in which the qualities of magnetic materials are to be considered the relation between the induction and the field is generally considered to follow either a linear or an elliptical law. Neither of these hypotheses can give a complete idea of the phenomenon and its consequences. S. P. Thompson has shown how to obtain the exact law relating the induction with the field, starting from the experimental static loop of hysteresis and developing it in a Fourier's series. But this method is long and laborious. The author has therefore devised a method which, utilising some experimental data easily obtained and taking into account some characteristics of the hysteresis loops, allows us to determine the values of the coefficients of Fourier's series, without necessarily tracing the magnetic loop of the substance considered and without having recourse to a harmonic analysis of it. In the development of the present article the terms of the Fourier series are limited to the 5th harmonic.

The conditions which the hysteresis loop must satisfy are the following:—(*a*) The loop is symmetrical; (*b*) the tangents at the summits of the two branches of the loop are coincident; (*c*) the inclination of these tangents to the axis of the fields is less than in any other point; (*d*) only a point of inflection exists in each branch of the loop. The data which must be obtained experimentally are the following:—(*e*) The max. intensity of magnetisation $I_{\text{max.}}$ corresponding to the maximum field $H_{\text{max.}}$ (*f*) The ratio η between the surface of the loop and that of the rectangle described around it. (*g*) The values of the magnetic susceptibility at the summits and the mean throughout the loop.

Condition (*a*) means that the even harmonics are nil. The equation of the hysteresis loop is, consequently, supposing $H = H_{\text{max.}} \sin a$, $I = v_1 \sin a + v_3 \sin 3a + v_5 \sin 5a + u_1 \cos a + u_3 \cos 3a + u_5 \cos 5a$.

The analytical translation of the conditions from (*b*) to (*d*) furnishes six equations and one inequality, from which the coefficients v_1, v_3, v_5, u_1, u_3, u_5, are drawn out and a limiting condition is obtained for the validity of the analytical development. This limiting condition consists in fact that the value of η must not be larger than $0{\cdot}245\,(1 - s/I_{\text{max.}})$, where s represents the ratio of the magnetic susceptibility at the summits of the loop to the mean susceptibility throughout the loop. In practical cases the ratio $s/I_{\text{max.}}$ is negligible compared with unity: in these cases the expression for the intensity of magnetisation is the following:—

$$I = \frac{I_{\text{max.}}}{64} \cdot \left[70 \sin a + 5 \sin 3a - \sin 5a - \frac{256}{\pi} \eta \cos a - \frac{128}{\pi} \eta \cos 3a - \frac{25{\cdot}6}{\pi} \eta \cos 5a \right]$$

The author gives the outline of the curves obtained from this expression for the cases of $\eta = 0$, $\eta = 0{\cdot}245$ and $\eta = 0{\cdot}368$. In this last case the curve is bad, as the value of η is larger than 0·245, which is the max. value admissible. The curves corresponding to the values 0 and 0·245 reproduce well the magnetic characteristics of steel and hard iron, but not those of annealed iron, since the residual magnetism so obtained is much less than the actual value. For this last case it is necessary to add to the general analytical expression the term $u_7 \cos 7a$ and to satisfy the condition $u_1 + u_3 + u_5 + u_7 =$ residual intensity of magnetisation. An analytical development analogous to that of the former case will furnish the values of the seven coefficients of u and v.

Condition (*b*) is not generally satisfied in practice. Nevertheless, the analytical development aforesaid can still be employed by substituting for the real loop an ideal one of the same area but having a common tangent at the summits, the arithmetical mean of the two real tangents at the same points. E. B.

200. *The Relations among the Ferro-magnetic Parameters.* **G. Vallauri.** (Elettrotecnica, 4. pp. 498–508, Oct. 5; 514–523, Oct. 15; 602–607, Dec. 5; 625–631, Dec. 15, and pp. 638–648, Dec. 25, 1917.)—This study is the development of a theme proposed by the Academy of Physical and Mathematical Sciences of Naples in order to find out, if possible, the relations between permeability and magnetic hysteresis and, especially, between the permeability coefficient and that of hysteresis of the Steinmetz formula.

The author has divided his study into four parts, namely: Generalities, Theory, Experiments, and Conclusions. In the first part are given the precise definitions of the different magnetic quantities: magnetic induction, permeability, alternating hysteresis, rotating hysteresis, susceptivity, differential susceptivity, reversible susceptivity, etc., and these quantities are illustrated by diagrams. The study is essentially limited to alternating and symmetric magnetisation, though in the following part an attempt is made theoretically to explain rotating hysteresis.

The second part deals with the theories of magnetisation. That of Ewing, though furnishing satisfactory explanation of the fundamental magnetic phenomena, does not allow us to derive from it quantitative consequences. The theory of Langevin and Weiss furnishes a curve of magnetisation which roughly resembles the real curve, but it does not explain the phenomenon of hysteresis, as, according to this theory, such hysteresis cannot exist, the curve of magnetisation being reversible. Weiss was, therefore, led to make some particular hypothesis regarding the intensity and the direction of the molecular magnetisation. But these hypotheses have no physical interpretation and could be made also without having recourse to the conception of a molecular field ; they are postulates as to the properties of the matter.

The only attempt to deduce from the Langevin-Weiss theory a relation between H and I was made by Kunz [Abs. 1444 (1912)] and improved by Vallauri [Abs. 875 (1913)]. The author develops the subject analytically, and although the curves of the hysteresis losses, the susceptivity, etc., differ considerably from the real ones, nevertheless the following important relation can be obtained from it : The hysteresis losses are inversely proportional to the susceptivity or to the differential susceptivity, or directly proportional to the coercive force.

The theories of Gans and Hertz, Williams, McLaren, and Volterra, and the empirical formulæ of Cisotti, Lamont, Frölich, Mullendorf, and Madelung are analysed, but they do not furnish any help in attaining the author's purpose.

The deductions of the different theories are, therefore, of no use, except that of Langevin-Weiss, the results of which can serve as a guide for the direction which should be given to the attempts to derive from the experiments the required relations among the parameters of ferromagnetism.

The third part of the study deals with the experimental results. A large number of publications were examined by the author, but, owing to incompleteness, only a very limited number of them could be utilised. For this reason it was possible to collect sufficiently complete data only for 14 materials, comprising all types of iron from annealed iron to silicon steel. The fact is worth noting that a sample of iron in the form of tube, though presenting the same hysteresis losses, had very different susceptivities when longitudinally or circularly magnetised. This fact has led the author to doubt the possibility of finding the required relation.

The attempts to deduce from these data a relation between the susceptivity and the hysteresis losses gave no results ; but better results were obtained by considering the coefficient η' of the Steinmetz formula $W = \eta' \times I^{1\cdot6}$ and the max. susceptivity $K_{\text{max.}}$. The relation $\eta' \times K_{\text{max.}} = 20\cdot4$, though roughly approximate, can be of some utility. The mean error was 14 % ; but as "error" must be understood, that of the relation just reported compared with the physical law shown by the experiments. The variations of η' are tolerably small, for values of I between 150 and 1250. Other attempts to find a relation between η' and the mean, the differential, and the mean of the differential susceptivities, etc., gave no results.

The author has verified the formula $\eta' \times K_{\text{max.}} =$ constant for two series of data published by Gumlich and Rogowski and by Yensen, which could not be utilised for obtaining the formula. The value of the constant was found to be 20·7 in the first case, and 20·6 in the second ; these agree with the value 20·4 found by the author. The approximation is respectively

25·5 % and 17·1 %. The "errors" are not uniformly distributed throughout the field of variation of I; for materials of high susceptivity the product $\eta' \times K_{max.}$ of the experimental values is generally greater than 20·4, whilst for materials of low susceptivity the same product is less than 20·4. It appears, therefore, justifiable to attempt to represent the relation between η' and $K_{max.}$ with a formula less simple than their simple product. As a matter of fact, the formula $\eta' \times K_{max.}^{0·882} = 8·08$ gives a better approximation, the mean error of 49 samples being 17·4 %.

By neglecting 1 compared with $4\pi K_{max.}$ the relations between $\mu_{max.}$ and η of the Steinmetz formula $W = \eta \times B^{1·6}$ can be obtained; these relations are the following: $\eta \times \mu_{max.} = 4·51$, $\eta \times \mu_{max.}^{0·882} = 1·15$.

A large number of diagrams and tables and a complete bibliography are contained in the article. E. B.

201. *Magnetic Storms, Faculæ, and Sun-spots.* **H. Arctowski.** (Comptes Rendus, 165, pp. 713–715, Nov. 19, 1917.)—From 1882 to 1903 E. W. Maunder registered 16 great magnetic storms observed at Greenwich.

The sum of the projected areas of the spots (umbra and penumbra) observed on the days of magnetic storms being expressed by 100, the numbers corresponding of the seven days preceding these dates are :—

Days	−7	−6	−5	−4	−3	−1	0
Spots	58	73	75	86	99	102	100

and the means of the nine days following those of the great magnetic storms are :—

Days	+1	+2	+3	+4	+5	+6	+7	+8	+9
Spots	98	84	72	61	52	44	38	35	31

On the average there is then a maximum of sun-spots on the days before those of the magnetic storms. But this maximum is not perfectly characteristic, considering that the two days that precede it, as also the two days that follow it, furnish values practically identical. Besides, the curve expressing the figures graphically is not symmetrical. There are fewer spots after the magnetic storm than before. These facts confirm the results obtained by Loomis and by Kelvin.

Particular cases, not agreeing precisely between themselves, are next considered, and the author remarks that if the magnetic storm cannot be provoked by the aggregate of the spots but only by one of those emitting a pencil of β-rays directed so that the earth traverses it, then it is evident that a maximum of spots simply denotes a great probability that such an occurrence will take place. Another correlative factor is furnished by the statistics of solar faculæ.

In the case of the 16 great storms discussed, the minima characteristic of faculæ (projected areas) observed from the fourth day before the date of the storm up to the day following are as follows :—

Days	−4	−3	−2	−1	0	+1
Number of cases	1	1	5	4	3	2

The magnetic storms are thus favoured by the coexistence of a maximum of spots and a minimum of faculæ. The quotient of the areas occupied by the faculæ and by the spots proves this more evidently. Figures are given to support this argument. On an average the day before a storm is characterised by a minimum in the ratio of areas of faculæ and of spots.

The author adds that a max. development of spots is followed by a max.

development of faculæ, occurring as a mean 9 days later, and it seems that it is justifiable to admit that those spots which are in course of formation act preferentially upon the terrestrial magnetism. Thus it may be supposed that the facular cloaks coming later, and also other veils of vapour, less apparent, absorb the emissions and only exceptionally allow of the spots projecting sprays of the electrons which hypothetically provoke magnetic storms.

The high luminosity of the faculæ may be attributed to the same cause, and thus may be a phenomenon of electro- or radio-luminescence. E. O. W.

RADIOGRAPHY AND ELECTROPHYSIOLOGY.

202. *Oscillatory X-ray Tube for applying very High Doses to Deep-seated Lesions.* (Archives d'Él. Médicale, 25. pp. 551–554, Dec., 1917.)—The difficulty of applying sufficiently intense radiation to deep-seated lesions without injury to the healthy skin has been a problem which lately has excited much interest. Attempts have been made to overcome the difficulty by moving the tube to two, three, or a very large number of different positions instead of applying the whole dose from any one point. This method is unsatisfactory when done by hand, because of the waste of time and the uncertainty as to whether the max. effect is produced at the point required. The present apparatus is so arranged that the tube is displaced automatically above the patient by a mechanical apparatus, which is in principle like a large metronome having a horizontal arm carrying the tube. By this means the tube moves in an arc and the part upon which the rays are required to act remains always along the normal. In this manner the radiations are spread over a comparatively large area of the surface while they are concentrated upon the deeper parts. There still remains the fact that even with such an arrangement some parts of the surface are subjected to much more intense radiation than others, but this has been annulled by suitable screens and by regulating the velocity of movement of the tube along the arc.

A. E. G.

203. *New Method of extracting Foreign Bodies, using a Radioscopic Screen. Method of Connected Shadows.* **Mazérès.** (Comptes Rendus, 165. pp. 397–398, Sept. 17, 1917.)—This method appeals by its simplicity. No special apparatus is required beyond the bulb, screen, and a pair of pincers. The point of incision being chosen, the tip of the pincers is placed in the incision made in the skin and the screen is put in position. The object then is so to arrange the pincers that the prolongation of its shadow on the screen shall cut that of the projectile for two different positions of the bulb. When this has been done the direction of the pincers gives the line of incision leading to the foreign body. The method of procedure when the shadow does not fall in the correct line is dealt with in detail. A. E. G.

204. *Localisation of Foreign Bodies by the Tauleigne-Mazo Radiostereometer.* (Archives d'Él. Médicale, 25. pp. 463–469, Oct., 1917.)—The apparatus furnishes measurements of the depths as well of those of size, in addition to anatomical localisation. Being based on a different principle, it corroborates results obtained by other methods. The radiostereometer consists essentially of a stereoscope with glass on two sides, and a network of lines or a micrometer for measuring purposes. Details of the stereoscope and measuring apparatus are given as well as the method of employing the micrometer. [See also Abs. 1872 (1917).] A. E. G.

CHEMICAL PHYSICS AND ELECTRO-CHEMISTRY.

205. *Chemical Reactions in the Corona.* I. *Ozone Formation.* **F. O. Anderegg.** (Am. Chem. Soc., J. 39. pp. 2581–2595, Dec., 1917.)—Among the problems of the present time is the question of the nature of the forces which hold the atoms together in the molecule. The most probable suggestion is that these forces are due to the electrons and positive nuclei of the different atoms acting on each other according to laws still obscure. Most of the articles published on this problem are of a speculative nature, and if the forces are electrical the author opines that some electrical method may give a solution. From the probability that the presence of ions in gases is the cause of new combinations of the atoms, and with the object of securing the least complicated conditions for the study of fundamental relationships, the author discusses a theory of ozone formation to be applied to the various known types of ozone preparation. Apparently the formation of ozone requires oxygen atoms which may be derived from molecular oxygen or from some compound of oxygen with other elements. On this basis, in accordance with the mass-section principle, any factor which increases the atomic oxygen concentration ought to raise the yield of ozone, and therefore an examination has been made of those reactions by which ozone is formed either directly or as a by-product; it is shown that this proposed viewpoint is not incompatible with the facts. The methods of ozone formation studied include :—Oxygen in a nascent or atomic condition; oxygen atoms from oxygen molecules by electrical discharge, radio-activity, light of a sufficiently short wave-length, hot bodies, and slow oxidation. The atomic oxygen requisite for the ozone formation may or may not be charged. The ions tend to pull apart the molecule into the more reactive atomic condition, and if the atoms that do react are not charged, then the action of ions is only an indirect cause of chemical reaction. Strutt has concluded that the active modification of nitrogen produced by a condensed discharge was composed probably of uncharged atoms. Duane and Wendt have shown that the reactive modification of hydrogen produced by α-radiation is composed of uncharged particles.

To test these views and to throw some light on the relationships between ionisation and chemical reaction the study of certain of the chemical reactions in the corona has been begun by an examination of the formation of ozone from oxygen in the corona discharge. The first phase of the reaction studied concerns the production of an equilibrium between ozone, oxygen molecules and oxygen atoms whether charged or uncharged. That oxygen does occur in the atomic condition has been proved by Warner to be due to the ionisation of the gas and not to the heat effect which does develop with time. Very full experimental details are given in the paper, accompanied by curves and an apparatus diagram. H. H. Ho.

206. *Study of the Allotropy of Cadmium.* **F. H. Getman.** (Am. Chem. Soc., J. 39. pp. 1806–1816, Sept., 1917.)—Earlier work by Cohen points to the existence of three allotropic modifications of cadmium. The author has prepared cells according to the scheme $\overset{-}{\mathrm{Cd}} - \frac{1}{2}\ \overleftarrow{\text{sat. sol. CdSO}_4} - 8\ \%\ \overset{+}{\mathrm{Cd}}$ amalgam and measured their e.m.f.'s at temperatures between 0° and 70° C. At 20° the initial e.m.f. gradually diminished, but ultimately it attained a

constant value. On heating a cell stabilised in this way the e.m.f. was shown to be a decreasing linear function of the temperature up to 40°. Above 40° C. the temperature coefficient underwent a reversal of sign. Stabilisation was effected by heating to 95° C. for several days. The e.m.f. of such a cell was found to be an increasing linear function of the temperature above 40° C. The rate of the increase above 40° was slightly less than the rate of decrease below 40°. Interpolation formulæ derived from the experimental data indicated that the temperature at which the e.m.f. reached its minimum value was 37·5° C., which may be regarded as the transition-point in the system $Cd_\alpha \rightleftharpoons Cd_\beta$. No experimental evidence of the existence of more than two allotropes of cadmium between 0° and 100° C. was obtained.

F. C. A. H. L.

207. *Strength and Inner Structure of Mild Steel.* **W. E. Dalby.** (Inst. Naval Architects, Trans. 59. pp. 75–85 ; Disc., 86–91, 1917. Engineering, 103. pp. 319–320 ; Disc., 330–331, April 6, 1917.)—The author describes the process of solidification and crystal growth of metals, and illustrates his points by a number of excellent photomicrographs of steels of various carbon contents. Pearlite is described as a conglomerate of alternating sheets of cementite and ferrite packed in something of the order of 60,000 to the inch. The strength of the steel depends jointly upon the strength of the ferrite and the pearlite. A steel containing 0·9 % carbon, and having the pearlite fully developed has a strength of about 62 tons per sq. in. Experiments on pure Swedish iron indicate that the strength of pure ferrite will be about 16 tons per sq. in. From these values it is quite a simple matter to calculate the probable strength of any steel of known carbon content. The load-extension diagram of a 0·9 % carbon steel is strikingly different from those obtained on steels of lower carbon content, a point which is worthy of further investigation because it indicates that there is some discontinuity in the properties of material in the region of this composition. In the *discussion*, **H. C. H. Carpenter** was inclined to place the strength of pure ferrite at 17 tons per sq. in., and pointed out that in the calculation of the probable strength of steel, complications were introduced by the presence of varying amounts of other elements. **C. E. Stromeyer** pointed out the difference in the types of fracture produced when high- and low-carbon steels were broken by torsional fatigue.

F. C. A. H. L.

208. *Grain-size Inheritance in Iron and Carbon Steel.* **Z. Jeffries.** (Am. Inst. Mining Eng., Bull. No. 131. pp. 1883–1899, Nov., 1917.)—Contains a discussion of the paper by Howe [Abs. 1326 (1917)] on the supposed reversal of inheritance of ferrite grain-size from that of austenite. The conclusions reached are as follows:—(1) The ferrite grain-size in pure iron, the ferrite and pearlite grain-size in hypo-eutectoid steel, the pearlite grain-size in eutectoid steel, and the cementite and pearlite grain-size of hypereutectoid steel are not inherited from the grain-size of the mother austenite. (2) The only structural feature that is generally inherited from the austenite of hypo- and hypereutectoid steels on cooling through their transformation ranges is the position of the excess ferrite or cementite at the austenite grain boundaries. Rapid cooling through the transformation range will cause the non-inheritance of this structural feature. (3) The austenite grain boundaries are nearly always effaced in pure iron and steels during the *Ar* transformations. (4) The grain-size refining is brought about by the combined effect of non-inheritance of the transformation products during heating and cooling. (5) In general,

in both iron and steel, the larger the austenite grain-size, the larger will be the size of the transformation products. An exception to this rule is found in very pure iron such as electrolytic iron. (6) In iron and steel, the larger the ferrite, cementite, or pearlite grain-size, the larger will be the austenite grain-size on heating above the A*c* transformations, and *vice versa.* (7) The faster the rate of cooling of iron and steel through the transformation range the smaller will be the grain-size of the transformation products, and *vice versa.* (8) The faster the rate of heating iron and steel the smaller will be the austenite grain-size. (9) The greater the temperature gradient during the transformations in iron and steel on heating and cooling, the larger will be the grain-size. (10) If the grain-size of a transformation product in iron and steel immediately after the transformation is smaller than the equilibrium grain-size of that product under the existing conditions, the equilibrium grain-size will be established by the known laws of grain growth. (11) A single grain of any constituent in iron or steel, when forced by thermal treatment to undergo one of the transformations, must transform from at least one nucleus, but may, and nearly always does, transform from more than one nucleus.
C. O. B.

209. *Apparent Specific Volume in Solution.* **Le R. D. Weld** and **J. C. Steinberg.** (Phys. Rev. 10. pp. 580–582, Nov., 1917.)—In this paper, which is a continuation of a previous paper by one of the authors [Abs. 956 (1916)], the apparent specific volume of copper sulphate in solution, or the volume of the solution containing 1 gm. of the solute minus the natural volume of the pure water entering into it at the same temperature, has been determined. The authors find that there is a distinct minimum in the curve of apparent specific volume plotted against temperature, and the temperature of this minimum is lower the more water there is in mixture with the copper sulphate. The authors are of opinion that the phenomenon presents so many points of similarity to those of the minimum volume of pure and solvent water as to lead us to suspect very strongly that the phenomena are identical in nature, whether to be explained on the Röntgen complex molecule hypothesis or otherwise.
A. F.

210. *Effect of Sulphides on Gold Cyanide Solutions.* **V. Pasukhin.** (Rev. de la Soc. Russ. de Métal. 1. pp. 161–172, 1916. Rev. de Mét. 14E. pp. 237–240, Sept.–Oct., 1917.)—According to J. Park (The Cyanide Process, 1906) and J. E. Clennel (Cyanide Handbook, 1910), the presence of metallic sulphide should lead to a precipitation of gold from its cyanide solutions, and thus interfere with the gold extraction. The author's researches (at Tomsk) do not confirm this statement. He prepared two gold solutions, precipitated the gold by various means in the colloidal state, and dissolved it in 8 % KCN to gold percentages of 0·0184 and 0·0085. He also prepared, by fusion or precipitation, the sulphides of Cu, Fe, Zn, Pb; he then mixed 5 gm. of any of these sulphides (also of Na_2S, matte, and some minerals, blende, auripigment, pyrite, etc.) with 100 cm.^{3} of the gold solution, and agitated for 12 hours; in no case was the gold concentration altered by the addition of these sulphides. In the second series of experiments he prepared the sulphides Cu_2S, FeS, PbS, as before, but alloyed the metal (Cu, Fe, Pb) first with gold. He then extracted these sulphides under agitation for 48 hours with KCN solution; the extraction was satisfactory in all cases, and perfect (100 %) in the case of the Cu_2S, which itself dissolved in KCN, whilst FeS, and especially PbS, do not react with KCN.
H. B.

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